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# EDITORIAL.

## ITEMS AND NOVELTIES.

**Barker's Improvement in Heating and Ventilation.**—The accompanying report upon this excellent device, to which reference has several times been made by descriptive articles in this journal,* will be read with interest by all who give attention to this important subject:

HALL OF THE FRANKLIN INSTITUTE,
*Philadelphia, Feb. 16th*, 1874.

The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania, for the promotion of the mechanic arts, to whom was referred for examination George R. Barker's Combined Heating and Ventilating Flue Apparatus, report that they have carefully examined Mr. Barker's apparatus for ventilation, both in model and as exemplified in the Franklin Institute building, and conclude that it is the best in efficiency and simplicity that has been brought to our notice. The combination is a very ingenious one, and the experiments submitted prove that the inventor's claim will be well sustained. A description of the apparatus is published in the "Journal of the Franklin Institute" of May, 1873, accompanied by a cut which explains its workings very fully.

Very respectfully,

ADDISON HUTTON, *Chairman*,
JAMES H. CRESSON,
CHAS. S. CLOSE.

By order of the Committee.

D. SHEPHERD HOLMAN, *Actuary*.

* Vide Jour. Frank. Inst., Vol. LXV, p. 292, and Vol. LXVI, p. 368.

**Increase of Resisting Power of Metals under Stress.**—In our issue of December last, p. 374, we announced the discovery, made a few weeks earlier,—at the time of the meeting of the National Academy of Science at the Stevens Institute of Technology,—by Professor R. H. Thurston, of a gain in power of resistance observed in metals left under stress during periods varying from one to several days.

The formal announcement of this remarkable and important phenomenon was made to the American Society of Civil Engineers in November, and appeared simultaneously in the Transactions of that Society and in this Journal.

We have lately received, through the kindness of Professor Baird, a memorandum relating to experiments made Jan. 27th and 28th, 1874, by Com. Beardsle, which exhibit a similar action.

The experiments of Professor Thurston were made, with his "Autographic Testing Machine,"* upon a variety of metals; those now presented were made by the ordinary form of Tensile Lever Machine.

This memorandum is as follows:

"Test of Bloom Iron, *turned to* $\frac{1}{10}$*ths diameter (nearly)* $= \frac{1}{2}$ *square inch Section. January*, 1874.

"Lever ceased to rise at 24·300 pounds. It was then balanced by deducting 1225 pounds, and left, with a balancing strain of **23,075** lbs., from 2 P.M., Jan. 27th, till 7 A.M., Jan. 28th, *when it was found that the lever had raised*, and it took 125 lbs. to rebalance it.

"The strain was then put on gently, and *the lever continued to rise until it reached* **28,250** *lbs., when it ceased to rise and sank.* We balanced the lever at this point by deducting 2,150 lbs. strain.

| | | | |
|---|---|---|---|
| "Limit of E., 27th, | 24,300 | Balanced at | 23,075 |
| " 28th, | 28,250 | " | 26,100" |

In Professor Thurston's Note to the American Society of Civil Engineers, he states the increase of resisting power noted at a maximum of 25 per cent. in twenty-four hours.

The increase observed in the specimens just referred to is $100\,(26{,}100—23{,}075) \div 23{,}075 = 13{\cdot}1$ per cent. in seventeen hours.

The interest and importance attaching to the discovery of these facts to the engineering profession, as well as to science, make it eminently desirable that still further researches should be made on the effect of prolonged stress, compression as well as tensional, and with every variety of material.

* Journal of the Franklin Institute. April, 1873.

We would call particular attention to the fact that the action here noted is not merely a negative one, but, as observed by the original discoverer, is apparently not only an increase in power of resistance but an actual, positive increased molecular effort, as is shown by the rise of the lever during the period of rest in Com. Beardsle's experiment.

**A Note on the Resistance of Materials.**—By Prof. Robert H. Thurston.—The following is the text of the communication of Prof. Thurston to the American Society of Civil Engineers, on the subject of certain unexpected results manifested by metals under strain, to which reference was made in the *Journal*, (Vol. lxvi, p. 374). For the copy we are indebted to the Author.

On the 13th ultimo, an apparatus for determining the torsional resistance of materials, which I had designed for use in illustration of my course of instruction, and to which I had fitted an automatic recording attachment, was exhibited to the National Academy of Science, at the late session held at this place, for the purpose of showing the peculiar adaptability of the machine for the determination and analysis of the action of physical and molecular forces in resisting stress, and to illustrate the bearing of experiments already made upon scientific investigations of molecular relation.

At the close of the meeting, a test piece of wrought-iron was left in the machine, exposed to a strain which had passed the limit of elasticity, and with a distortion of 45 degrees, the intention being to determine whether, as has been suspected by some writers and by many engineers, "viscosity" is a property of solids; whether a flow of "solids"* could occur under long continued strain just equilibrating, when first applied, the resisting power of the material, or whether the "polarity" of Prof. Henry is an absolutely unrelaxing force.

The metal was left under strain twenty-four hours, and had not then yielded in the slightest degree. This result and the results of other similar experiments since made confirming it, indicate that metal strained far beyond the limit of elasticity, as above described, does not lose its power of resisting unintermitted static stress.

The important bearing of this fact upon the availability of iron, and of steel, which also behaves similarly, for use in constructions exposed to severe strains, is readily seen.

* Mon. H. Tresca; Sur l'Ecoulement des Corps Solides. Paris, 1869–72.

After noting the result obtained as stated, it was attempted to still further distort the test piece, when the unexpected discovery was made that its resisting power was greater than when left the previous day, an increase of resistance being recorded amounting to about 25 per cent. of the maximum registered the preceding day, and approximating closely to the ultimate resistance of the material. Repeated experiments, continued up to the date of writing, confirm the following previously undemonstrated principle: That iron and steel, if strained beyond the limit of elasticity, and left under the action of the distorting force which has been found just capable of equilibrating their power of resistance, gain resisting power to a degree which has a limit in amount approximating closely, if not coinciding with, the ultimate resistance of the material, and which had a limit as to time, in experiments hitherto made, of three or four days.

Releasing the piece entirely and again submitting it to the same force immediately, does not produce this strengthening action.

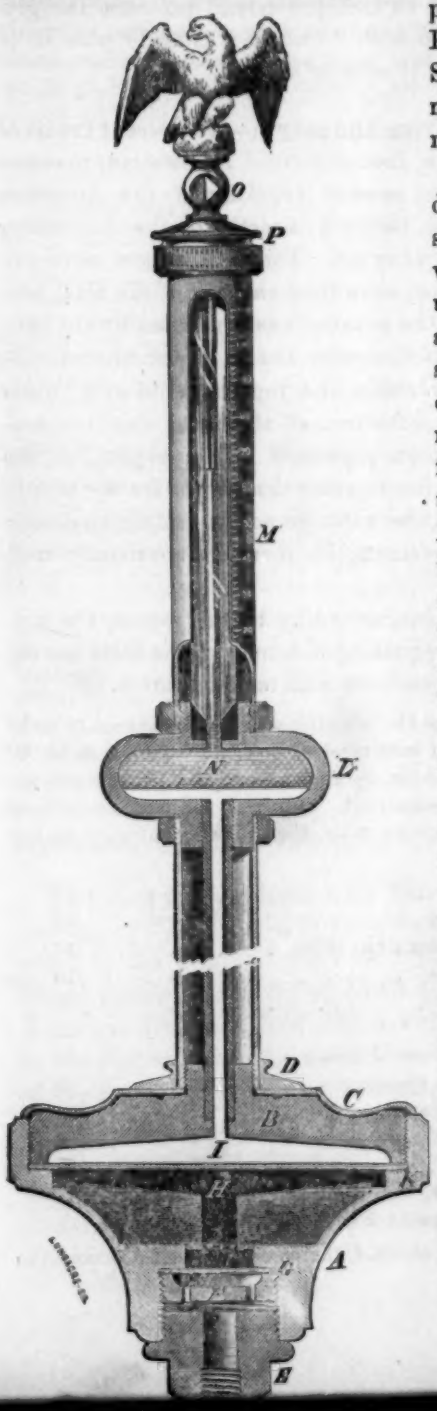
There is some evidence that is confirmed by theoretical dynamic principles, that the increase of strength noted is not accompanied by a change of resilience, but that the gain of resisting power is at the expense of a proportional amount of ductility.

The diagrams obtained during this research will be presented at a future time, when the investigation shall have been completed.

The interest and importance attaching to the discovery of the principles above enunciated, to our profession, as well as to science, will, I hope, justify the presentation of this note.

**A Third Alpine Tunnel** is now proposed. It is to pass under the St. Bernard and will be 20,000 feet long. Under the summit it is proposed to widen the tunnel so as to make a station, and to connect by means of an elevator with the open air. At the mouth of the elevator shaft a hotel will be built, so that Alpine scenery and sunrises may be enjoyed without any personal exertion.

**Reservoir Pressure Gauge.**—We herewith illustrate an improvement in the Mercurial Pressure Gauge of Mr. Thos. Shaw, by which the scale of measurement is greatly magnified.




The original invention was designed to permit of the measurement of great pressures with a comparatively short column of mercury. This was accomplished by the interposition of a plunger, *H*, which exposes a large surface to the mercury at *I*, and a small surface to the heavy pressure at the lower face of the plunger, *H*. The ratio existing between these areas will therefore indicate the reduction in length of the mercury column, by which device it is rendered possible to keep the length of the mercurial column within practical limit.

The illustration appended shows an improvement of the inventor, by which the scale of measurement is magnified by compounding two fluids—glycerin and mercury being employed, the result being a greatly magnified scale, which renders the instrument especially useful for elevated tanks or reservoirs, the contents of which it is desired to know. The mercury column is made of sufficient length to balance all the water in the pipes, however great their elevation, and at the top of the mercury column is a reservoir, *L*, where the mercury ends and the gly-

cerin, with a 12-fold increased movement, commences; that is, if the mercury moved one-quarter of an inch per pound pressure the glycerin moves three inches per pound, by which it is made possible to read the record in ounces when it may be desired.

**State and Statistics of Iron Industry.**—The recent report of the Secretary of the American Iron and Steel Association, presents an unfavorable resumé of the present condition of the American iron trade. This condition is ascribed directly to the depressing influences of the recent financial crisis. This will appear more evident, when it is remembered that more than *one-half* of the total iron production and importation of the country was consumed by the railroads. The immediate effect of the panic was to check almost completely the construction of new roads, and repairs to old ones, causing a great falling off in demand for iron of all kinds, which depression still continues. The opinion expressed in the report, to the effect that until railroad companies re-enter the market for the supply of all kinds of railway material there can be no general improvement in any branch of the iron business, is, therefore, obviously well founded.

The subjoined tables represent, according to the report, the condition of the iron trade at the beginning of January; the facts having been obtained by direct correspondence with manufacturers.

"*Rail Mills.*—Of 57 rail mills in the country, which are prepared to make rails of heavy sections, returns have been received during January, from 50. Of the seven not heard from, one is certainly known to be idle, leaving only six from which no information has been received. Of these six, four are mills of small capacity. From the 50 reporting mills, the following information has been received:

| | |
|---|---|
| Whole number of rail mills, | 57 |
| Number of mills making returns | 50 |
| " " " running December 31st, 1873, | 17 |
| " " " " full time, | 10 |
| " " " " half time, | 7 |
| " " " standing, | 33 |
| " " " proposing to resume January, | 10 |
| " " " uncertain about resuming, | 23 |
| " " hands wholly unemployed, | 11,490 |
| " " " employed half time, | 10,150 |
| " " mills selling rails, | 13 |
| " " " not selling rails, | 37 |
| Net tons of rails on hand and unsold, December 31st, | 36,744 |

"*Blast Furnaces.*—At the close of 1873, there were 650 blast furnaces in

the country, which were either making pig iron, or were prepared to make it. Returns have been received during January from 385 of these furnaces, or about three fifths of the whole number, showing the number of stacks in blast, the number out of blast, the number of tons of pig iron on hand and unsold on the 1st of January, and the number of hands then out of employment. These returns are tabulated below:

COMPLETE TABLE BY STATES.

| Name of State. | Stacks heard from. | Stacks in blast. | Stacks out of blast. | Stock on hand. Net Tons. | Hands unemployed. |
|---|---|---|---|---|---|
| Maine | 1 | 1 | 0 | 400 | None. |
| Vermont | 2 | 1 | 1 | 500 | 80 |
| Massachusetts | 2 | 1 | 1 | 536 | 45 |
| Connecticut | 7 | 6 | 1 | 3,632 | 78 |
| New York | 33 | 26 | 7 | 31,116 | 382 |
| New Jersey | 11 | 5 | 6 | 12,332 | 60 |
| Pennsylvania | 152 | 100 | 52 | 91,681 | 3,419 |
| Maryland | 15 | 12 | 3 | 10,801 | 673 |
| Virginia | 21 | 9 | 12 | 6,970 | 867 |
| West Virginia | 5 | 5 | 0 | 4,255 | 179 |
| North Carolina | 1 | 0 | 1 | None. | 60 |
| Georgia | 3 | 3 | 0 | 773 | 50 |
| Alabama | 8 | 6 | 2 | 6,249 | 210 |
| Kentucky | 11 | 8 | 3 | 12,150 | 300 |
| Tennessee | 12 | 6 | 6 | 9,615 | 500 |
| Ohio | 48 | 32 | 16 | 47,797 | 2,898 |
| Indiana | 7 | 0 | 7 | 10,378 | 500 |
| Illinois | 5 | 1 | 4 | 11,710 | 200 |
| Michigan | 18 | 12 | 6 | 21,254 | 666 |
| Wisconsin | 13 | 7 | 6 | 6,805 | 470 |
| Missouri | 10 | 6 | 4 | 19,476 | 885 |
| Total | 385 | 247 | 138 | 308,430 | 12,522 |

The report, furthermore, discusses at length the subject of tariff legislation, and relative topics of interest to the trade.

**The American Iron and Steel Association.**—At a recent meeting in Philadelphia, of the several independent organizations devoted to the iron and steel interests of the country, a union was effected between them, the consolidated body taking the name of "The American Iron and Steel Association." Such a union of forces can not be otherwise than favorable to the cause they represent. The report of the Secretary at the same meeting, contained a strong appeal for the formation of a scientific section of the Association, which should in its operation develop those features which have made the British Iron and Steel Institute so valuable. The report states that it was declared to be necessary, in the organization of the Association, to discuss practical and scientific subjects bearing upon the manufacture

and working of iron and steel; but that thus far, owing to a combination of unfavorable circumstances, this scientific phase of the Association has not received its proper share of attention. Now, however, that all conflict of interests has been effaced by consolidation, the reorganized body should, and doubtless will, strive to make it as representative of scientific metallurgy in America, as is its sister association of such progress abroad.

**A Chord of "Spheral Music."**—By Pliny Earle Chase.*—In various communications to the American Philosophical Society, I have pointed out simple harmonic relations between planetary distances, which seem to indicate a tendency to cosmical aggregation at harmonic nodes, in a vibrating elastic medium.

In a paper, read on the second of May last, I introduced the harmonic series, $\frac{7}{2}$, $\frac{7}{10}$, $\frac{7}{18}$, $\frac{7}{26}$, $\frac{7}{34}$, of which the unit is the earth's mean radius vector. Finding representatives for the other terms, I stated that the term represents "a possible unknown planet, planetoid group, or other seat of solar and planetary perturbation." By Kepler's law the cyclical period of such a perturbation would be about 51 days. I also suggested the Wolf's sun-spot period of 27 days "might be readily explained by the perturbations and transits of a planetoid or meteoric group, at a distance which would complete the terrestrial harmonic series."

Professor Winlock kindly allowed me to examine the measurements of the sun's spotted area, at the observatory of Harvard University. They indicated such a periodicity as I was looking for, but as the observations covered a period of less than five months, I did not regard them as conclusive.

I subsequently found in "Nature," of July 17th, an abstract of a communication to the Royal Society on June 19th by Messrs. De La Rue, Stewart and Loewy, who find evidences of a tendency in sun-spots "to change alternately from the north, or positive, to the south, or negative hemisphere, and *vice versa*," and "*that the two outbreaks are at opposite ends of the same solar diameter.*" Their inferences are drawn from observations taken in three different years and covering an aggregate period of 407 days. Their lowest approximate estimate of the mean interval between two maxima in the same solar hemispere is 22·25 days; the highest, 28 days; "the most probable mean

* Read before the American Association for the Advancement of Science, Portland Meeting, 1873.

value, 25·2 days." The interval between two maxima of the same sign and originating at the same axial extremity would, of course, be twice as great.

Herschel (following Bianchi and Laugier), Spörer, Carrington and Faye, give estimates of the suns sidereal rotations varying between 24·62 and 25.33 days. The evidence, therefore, seems conclusive, both of a cycle due to solar rotation, and of another, due to some disturbing influence which revolves around the sun in a period approximately equivalent to two rotations.

The half-periods, being all made sidereal, and the corresponding mean distances, compare as follows:—

| | Days. | Distance. |
|---|---|---|
| Spörer, . . . . . | 24·62 | ·263 |
| Carrington, . . . . . | 24·97 | ·265 |
| Faye, . . . . . | 25·07 | ·266 |
| Wolf, . . . . . | 25·14 | ·267 |
| De La Rue, Stewart and Loewy, | 25·20 | ·267 |
| Herschel, Bianchi and Laugier, . | 25·32 | ·268 |
| Harmonic prediction, . . . | 25·51 | ·269 |

**Smithsonian Meteorological Observations.**—From the subjoined letter it will be observed that the Institution formally transfers the system of meteorological observations, continued through many years, to the Signal Service Department. This transfer will doubtless be for the best interests of science, while it is a handsome acknowledgement of the services of the Signal Service.

SMITHSONIAN INSTITUTION, WASHINGTON, D. C., 2d February, 1874.

*To the Voluntary Meteorological Observers who have reported to the Smithsonian Institution:*

It has been from the first a part of the policy of this Institution to devote its energies to no field of research which can be as well cultivated by other means; and the United States Government having established a system of meteorological observations, and having made appropriation for its support, we have thought it for the best interest of the science to transfer the system of meteorological observations which has been so long continued by the institution to that of the War Department, under the Chief Signal Officer, Gen. Myer.

The propriety of this transfer will be evident from the fact that the Institution has not the means of paying for printing blanks, postage, and the calculations and monthly publication of the results, and that the assistance which has heretofore been rendered, in this way, by the Department of Agriculture is now discontinued; furthermore, Gen. Myer can combine these observations

with those made with standard instruments now under his charge, and out of the whole form a more extended and harmonious system than any at present in existence.

We trust this transfer will meet the approbation of the observers generally, and we hope they will continue their voluntary coöperation—not with the expectation of being fully repaid for their unremitted labor, in many cases for a long series of years, but from the gratification which must result from the consciousness of having contributed to increase the sum of human knowledge. We trust also that the observers will continue to cherish an interest in the welfare and progress of the Smithsonian Institution, while, on our part, we shall in all cases and at all times, be pleased to continue to answer any communication which may be addressed to them on scientific subjects.

We shall retain for the present all the records of observations which have been accumulating at the Institution during the last twenty-five years, and continue the work of their reduction and discussion up to the end of the year 1873.

The investigations relative to the rain up to 1866 have been published, and a supplement will be published giving the results since that time.

The temperature investigations are nearly finished, and those relative to the winds will be completed in the course of a month or two. The publication of the results will be made as rapidly as the means at our command will warrant. It is scarcely necessary to say that copies of these works will be distributed to all observers who have contributed the materials upon which these researches are based.

Very respectfully,

Your obedient servant,

JOSEPH HENRY,

*Secretary Smithsonian Institution.*

**The Coagulability of Serum and Albumen.**—Messrs. Mathieu and Urbane have recently presented some novel and important facts relative to the above heading in a paper read before the French Academy. They assert that if the gases dissolved in the serum of the blood are completely removed, an albuminous liquid is obtained, which does not coagulate even at a temperature of 212°. The same fact was found to hold good with egg albumen when the gases were removed therefrom by suitable pneumatic apparatus. Further investigation, according to the authors, demonstrated the fact that the greater portion of this gas consists of carbonic acid, and that it is really to the presence of this that the property of coagulation is to be ascribed. It was found to be possible, furthermore, to restore the property of coagulating by heat to albumen thus treated, by simply introducing into it a sufficient quantity of carbonic acid.

It is quite probable that the ability to remove the coagulability of albumen by extracting the carbonic acid which it contains, and to re-

store it by supplying it by artificial means, may be found to be of value in many industrial operations in which albumen is employed.

**Mineral Cotton.**—Under the heading of "A new Incombustible and Non-conducting Material," the "American Artisan" makes reference to an article presented at the Vienna Exposition by an establishment at Osnabrück, to which, from its peculiar qualities and its origin, the name of *slag-wool* (schlackenwolle) is applied. This material, it is further stated, is made from the slag of a cupola furnace, by directing upon it in its fluid state, as it runs from the furnace, a strong jet of steam, by which treatment the slag is thrown, in the condition of fine fibres, into a cast iron chamber or receptacle, from which it is gathered in a form resembling wool. It is further stated that experiment has shown it to be an excellent non-conductor, on which account a variety of uses are predicted for it. Especially is it recommended as a coating for steam pipes, about which it is stated it may be wrapped, without reference to bends, angles or convolutions, with the same facility with which wool itself could be applied.

By reference to the files of this journal,* our readers will perceive that this material has been known for some years in this country, and its application as a non-conductor of heat, secured by letters patent, although it has not been introduced into general use. The statement of our contemporary concerning the admirable non-conducting qualities of the material is quite correct. It was first presented to the notice of the public, at the stated meeting of the Franklin Institute in November, 1871, by the President (Mr. Coleman Sellers), and from the subsequent report of the Committee of Science and the Arts, to whom it was submitted for examination into its merits, it was found to have quite superior non-conducting qualities, as indeed might be predicted from its nature, and from the great quantity of air which its feathery condition permits it to retain.

The extreme brittleness of the material, however, renders doubtful the assertion that it may be successfully applied to steam pipes or boilers, without some cementing material like lime, or other artifice, to retain it permanently in place. So brittle is it, indeed, that it readily breaks up into the finest spiculæ, which at the least disturbance fill the air, and make it quite unpleasant to handle it even for a short time.

* Vol. lxvi, p. 361.

**Phosphor-Bronze.**—We have referred to the results of experimental trials with the new alloy, "phosphor-bronze." We observed that the phosphor-bronze had been employed to advantage for the great bearings of the plates in general rolling mills, and for conical gearing in universal rolling mills, in cases where the rollers weighed five tons. It was found that the gear, when made of hard cast-iron, broke frequently; this was replaced by wheels of ordinary bronze, and finally by wheels of phosphor-bronze. The duration of the ordinary bronze wheels did not exceed, on an average, five months, while those made of phosphor-bronze lasted for about nine months. The phosphor-bronze has also been applied not only in the making of pinions but in the driving axles of mills; in the latter case the superiority seems to depend not on the hardness, but upon the very great resistance of the alloy. To form a just idea of the value of this remarkable substance, no better evidence could be offered than the estimate placed upon it by the several juries in the mechanical department of the Vienna Exposition, where it obtained the following awards, viz.: In group 1, for cog-wheels, tuyeres, and bearings, the diploma of merit; in group 7, for revolvers and parts of harness, the medal of progress; and in group 12, for its application to guns and other material, the medal of merit. Unlike other alloys, it can be remelted without any material loss or deterioration of quality; while heavy steel castings on the other hand, when worn out or broken, are comparatively worthless. A great variety of objects hitherto worked in iron and steel may now be cast in phosphor-bronze with advantage, and in many cases they required only a polish to make them ready for use; in addition to which they possess the merit of not corroding. Its great fluidity, compactness, and fine grain, as likewise its beautiful color, are qualifications which adapt it eminently for decorative art, and the perfection of the castings materially reduces the cost of subsequent chasing and finishing. The phosphor-bronze alloys made for railing, drawing, or embossing, will stretch more than copper, or any of its ordinary compounds. Plates have been reduced by a single cold rolling to one fifth their thickness, the edges remaining perfectly sound and without crack. Another advantageous property of the new alloy resides in its incapacity to emit sparks. Tools, knives, scissors, and other articles, such as locks, keys, etc., have on this account already been largely adopted by manufacturers of gunpowder.

Several governments have experimented on the new alloy as to its adaptability for making cannon. Without exception the result showed

a much greater resisting power than that displayed by ordinary bronze. In Prussia it was shown, in firing with the regulation charges, and diminishing at each fifty shots the exterior diameter of the chamber, that the phosphor-bronze cannons changed their dimension only when the thickness of the metal was below that of the dimensions of a cannon of the same calibre of steel. The Belgian government has adopted the phosphor-bronze for small arms and for the harness metal of its cavalry. From the brief space of time it has been before the mechanical world, not less than from the modifications of which its physical properties are susceptible by slight variations in its constitution, it is fair to presume that the uses to which it may be advantageously applied have as yet by no means been fully recognized.

**Deposits in Boiler Flues.**—Concerning the formation of deposits in boiler flues, about which a considerable amount of speculation has been published, Prof. Hayes give the following opinion in a late issue of the American Chemist: These are of two kinds, both of which are capable of corroding the iron rapidly, especially when the boilers are heated and in operation. The most common one consists of soot (nearly pure carbon) saturated with pyroligneous acid, and contains a large proportion of iron if the deposit be an old one, or very little iron if the deposit has been recently formed. The other has a basis of soot and fine coal ashes (silicate of alumina) filled with sulphur acids, and containing more or less iron, the quantity determined by the age of the deposit. The pyroligneous deposits are always caused by want of judgment in kindling the fires. The boiler being cold, the fires are generally started with wood; pyroligneous acid then distills over into the tubes, and collecting with the soot already there from the first kindling fires, forms the nucleus for the deposit, which soon becomes permanent and more dangerous every time wood is used in the fire-place afterwards. The sulphur acid deposits derive their sulphur from the coals used; but the base, holding their acid, is at first occasioned by cleaning or shaking the grates, soon after adding fresh charges of coal. Fine ashes are thus driven into the flues at the opportune moment for them to become absorbents for the sulphur compound distilling from the coals, and the corrosion of the iron follows rapidly after the formation of these deposits.

**The Centennial Exposition.**—It is the proposition of the United States Centennial Commission to make a portion of the buildings necessary for the Exposition of 1876 a permanent structure, which will be called Memorial Hall, and shall always remain as a commemoration of the great event. It is designated for use during the exhibition as the Art Gallery, and eventually as a National Art Museum.

As it will be built with funds especially contributed for that purpose by the State of Pennsylvania and the City of Philadelphia, the approval of the design was vested in the State Board of Supervisors, a body appointed by the State Legislature.

The architects are Messrs. Collins and Autenreith, of Philadelphia, who obtained the first prize in the final competition.

The building will be located on the Landsdowne Terrace, immediately north of the main pavilion, with which it will be connected by a wide covered approach or corridor 175 feet long.

Our cut represents a view from the northwest side, as seen from the drive at the foot of the terrace, after the temporary buildings are removed.

The general outline of the plan of the proposed building is a cross with arms respectively 420 feet and 320 feet long; width of each, 123 feet; average height above the floor, 70 feet. A dome rises from the intersection, and four towers which appear clear and complete in outline from the ground up. From the top of the figure on the dome to the level of the terrace is 284 feet.

It is proposed to use stained glass for the windows of the dome, and to use the central rotunda as a general resort for visitors, and not for exhibition space.

Four large stairways lead out from the rotunda up to the galleries.

The basement is to contain retiring rooms, boilers for heating, and ample offices for the Park police; there is likewise an entrance for heavy teams carrying marbles, bronzes, etc., and in two of the towers elevators for the proper distribution of such articles upon the different floors.

## Bibliographical Notices.

*Wheeler's Natural History Charts.*—Prof. C. Gilbert Wheeler, of the University of Chicago, has issued a series of five charts, very correctly and handsomely illustrating the following subjects: Mammalia, Birds, Amphibians and Fishes, Intervertebrates and Minerals, Rocks and Fossils.

THE CENTENNIAL EXHIBITION, PHILADELPHIA, 1876. THE PROPOSED MEMORIAL HALL.

The charts contain upward of 700 illustrations, in which the natural colors of the various objects are faithfully given. The plates are lithographed and carefully and laboriously colored by hand, a mode of execution confined almost exclusively to the scientific monographs or the publications of learned societies. The animals have a life-like and animated appearance, and the minerals are faithfully reproduced, with their natural luster. In addition to leading fossils, and stratigraphical geology, there are a large number of special illustrations of crystallographic forms. Each chart is made up of five sheets of plates, fourteen by twenty-four inches, with two columns of text, running the whole length of the chart. This text, though concise, is fully descriptive, and, with some additional matter, is published in book form. Now, that natural history has become so important and indispensable a branch of education, and that every teacher is bound to pass an examination in that specialty, the possession of charts such as these will prove very desirable in schools and public institutions.

We particularly commend them to the notice of teachers in country towns, where facilities for obtaining the specimens usually stored in museums are not available. The publishers are A. S. Barnes & Co., Chicago and New York.

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# Editorial Correspondence.

## AN ACCOUNT OF A STEAM BOILER EXPLOSION.

*Editor of the Journal of the Franklin Institute:*

Dear Sir.—The following account of a very destructive steam boiler explosion, which occurred about six months ago, is not only valuable for the completeness and reliability of the facts connected with it, but instructive in its results. It is derived from the notes of an able ex-engineer of the Navy, who witnessed it from the distance of a few hundred yards.

The boiler was built of the best quality of iron, about the year 1854, by McCarter Brothers, of Norristown, for Mr. John Wood, of Conshohocken, Pennsylvania, for use in his rolling mill. It was cylindrical, 44 inches in diameter, and 24 feet in length, with two interior cylindrical flues of 16 inches diameter each. The thickness of the iron in the shell was originally five-sixteenths of an inch, but at the time of the explosion it was only three-sixteenths of an inch. The thickness of the iron in the flues was originally three eighths of an inch, but at the time of the explosion it was less than one-quarter of an inch. The heads of the shell, originally, were conical, but had become nearly flat. The seams of the entire boiler were single riveted with rivets of five-eighths of an inch in diameter.

This boiler was connected with several others by one main steam-pipe, and was heated by the escaping gas from a puddling furnace. It, like those, was provided with a separate stop-valve, gauge cocks and safety-valve, but had no separate pressure-gauge; there being

but one steam-gauge for all, and that was attached to the main steam pipe. The safety-valve was adjusted to a pressure of 80 pounds per square inch above the atmosphere, but nothing is known as to its fitness for use, or whether or not it was rusted to its seat. The latter supposition appears probable.

The boiler, on Saturday, had been shut off from the others by the closing of its stop-valve, and blown out, while they continued in use. On the Monday following, it was well filled with water, and the hot gas from a puddling furnace in full action was turned into the flues. No water was admitted after the hot gas was turned in, and no steam withdrawn either by escape from the safety-valve, or by use in the engines, for the stop-valve was allowed to remain closed, and the engineer states that no steam blew off at the safety-valve up to the time of the explosion. There being no steam-gauge on the boiler, the only indication of the great pressure within it was the unusual violence with which the water was observed to rush from the gauge-cocks just previous to the catastrophe.

The conditions, at the instant of the explosion, were then as follows: The boiler was well filled with water. The generation of steam was as rapid as an abundant supply of highly-heated gas from a puddling furnace could produce. The steam thus generated had no escape.

The explosion which quickly followed this combination of circumstances was tremendous in the extreme. The boiler was torn asunder in the middle, and one-half hurled about 300 feet, passing through a 2-foot thick brick wall into an iron tank weighing many tons, which it dislodged to a considerable distance. The boiler-flues were flattened, like a board, from end to end. The sheets of the boiler shell were rent through the solid metal in many places, while in others the fracture was through the rivet holes, and in still others the rivets were sheared. A considerable portion of the boiler was torn literally to shreds, and everything surrounding it demolished. The building containing it was made a complete wreck; not a boiler, puddling furnace, pipe, wall or column was left standing within a radius of 200 feet.

The explosion was unquestionably caused by a gradually, but *very rapidly*, accumulating pressure to beyond the boiler's strength of resistance. The accumulation was so rapid that both flues and shell simultaneously yielded—the one to compression, the other to extension—and the various fractures of the iron, in some places through the solid sheet, in others through the rivet holes, and in others by the shearing of the rivets, were mainly due to the suddenness of the ruptures, there being very little time for the stretching of the metal, or its gradual yielding, or slow transmission of strain.

I am of opinion that the phenomena of steam boiler explosion are much modified by the *rapidity* with which the pressure increases to the exploding point; and that the destructive capability of such explosions bears a very decided relation to this fact.

Very truly yours, B. F. ISHERWOOD,

*Chief Engineer U. S. Navy.*

# Civil and Mechanical Engineering.

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## THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

(Continued from page 34.)

### Belts for Transmitting Power.

The traction of belts upon pulleys, like that of locomotive wheels upon railways, being incapable of demonstration except by experience, hindered for a long time the introduction of belts as a means of transmitting motion and power. I mention motion separately because with many kinds of machinery that involve high speed, such as wood machines, the transmission of rapid movement must be considered as well as power, and it is only by means of belts that such high speeds may be communicated from one shaft to another; so that at least in practice, belts alone are at this time employed for high speed.

The first principle I will point out in regard to belts, distinguishing them from shafts as a means of transmitting power, is that the power is communicated by means of tensile instead of torsional strain, the power during its transmission being represented in the difference of tension between the driving and the slack sides of the belts.

In the case of shafts, their length, or the distance to which they may be extended in transmitting power, is limited by torsional deflection, and as this torsional strain is avoided with belts, we may conclude that, unless there are other disqualifying conditions, belts are better than shafts for transmitting power through long distances.

Belts suffer resistance from the air and from the friction in the bearings of supporting pulleys, which are necessary in long horizontal belts. With these exceptions they are capable of moving at a high rate of speed and transmitting power without appreciable loss.

Following this proposition into modern engineering practice, we find how experience has gradually conformed to what these properties in belts would suggest; wire and other ropes with a diminished cross section to avoid air friction, and allowed to droop in low curves to avoid supporting pulleys, are now commonly employed for transmitting

power through long distances. This system has been very successfully carried out in Germany and America, in some cases for distributing power in large manufacturing establishments.

Belts, among which are included all flexible bands, do not afford the same facilities for taking off power at different points that shafts do, but have advantages in transmitting power to portable machinery, or, in other words, when the power is to be taken off at movable points, as in the case of travelling cranes, hoists and so on.

An interesting example in the use of belts for communicating power to movable machinery is furnished in the travelling cranes of Mr. Ramsbottom, in the shops of the L. & N. W. Railway, at Crewe, England, where powerful travelling cranes receive both the lifting and traversing power by means of a cotton rope not more than one inch in diameter, which moves at a high velocity, the motion being reduced by means of tangent wheels and gearing to attain the force required in lifting heavy loads. In looking at this mechanism, those who had not their conceptions based on a true knowledge of power and the relations between power and speed, would see, in the effect of this small cotton rope, something marvellous.

Considered as means for transmitting power, the contrast as to advantages and disadvantages lies especially between belts and gearing instead of between belts and shafts. It is true in extreme cases, such as that cited at Crewe, or in conveying water power from inacessible places through long distances, and so on, the comparison lies between belts and shafts, but for ordinary practice, in three cases out of four, the problem as to mechanism for conveying power is between belts and gearing.

If experience in the use of belts was thorough, as it is in the case of gearing, and if the quality of belts did not form an important part in the estimates, there would not be much difficulty in determining where belts should be employed and where gearing would be preferable.

Belts are continually taking the place of gearing even in cases where they have been until very recently thought inadmissable; at least one of the largest rolling mills in Pittsburg, Pennsylvania, except a single pair of spur wheels as the last movers at each trains of rolls, is driven by belts throughout.

Leaving out the matter of a positive relative movement between shafts, which belts as a means of transmitting power cannot insure,

there are the following conditions that must be considered in determining whether belts or other means should be employed in transmitting power :

1. The distance to which the power must be carried. 2. The speed at which the transmitting machinery must move. 3. The course or direction of transmission, whether in straight lines or at angles. 4. Durability and the cost of construction. 5. The loss of power during transmission. 6. Noise, vibration and jar.

In every case where there can be a question as to whether gearing shafts or belts will be the best means of transmitting power, the several conditions named will furnish a solution if properly investigated. Speed, noise or angles may become determinative conditions, and are such in a large number of cases ; first cost and loss of power are generally secondary conditions.

Applying these tests to cases where belts, shafts, or wheels may be employed, and carefully considering the special conditions of any case, the apprentice will soon find himself in possession of knowledge to guide him in his own plans and enable him to judge of the correctness of examples that come under his notice.

It is never enough to know that any piece of work is generally constructed in some particular manner, or that such a proposition is generally accepted as being correct ; nothing is learned, in the true sense, until the reasons for it are understood, and it is by no means sufficient to know from observation alone that belts are best for high speeds, that gearing is best to form angles in transmitting power, or that gearing consumes more power, and that belts produce less jar and noise ; the reasons for these things and the principles that lie at the bottom must be reached before it can be assumed that the subject is understood.

### Gearing as a Means of Transmitting Power.

The term gearing, which was once applied to wheels, shafts and the general mechanism of mills and factories, has now in common use become restricted to tooth wheels, and is in this sense employed here.

Gearing as a means of transmitting motion is employed when the movement of parts of machinery must remain relatively the same —when a heavy force is transmitted between shafts that are near to each other, or when shafts are at angles to each other.

This rule is of course not constant, except as to cases where positive relative motion is essential ; noise and the liability to sudden ob-

struction may be reasons for not employing tooth wheels when the distance apart and the position of shafts would render such connection the most durable and cheap.

Gearing under ordinary strain, within limited speed and when other conditions admit of its use, is the cheapest and most durable mechanism for transmitting power, yet the amount of gearing employed in machinery, especially in Europe, is no doubt far greater than it will be in future and as belts are better understood.

No subject belonging to mechanics has been more thoroughly investigated than that of gearing; text-books are replete with every kind of information pertaining to gearing, at least so far as the subject can be made a mathematical one, and to judge from the amount of matter, formulæ and diagrams relating to the form of teeth that the apprentice will meet with, he will no doubt be led to believe that the main object of modern mechanics is to generate the teeth of wheels. It must be admitted that the teeth of wheels and the proportions of wheels is a very important matter to understand, and should be studied with the greatest care, but it is equally important to know how to produce the teeth in metal after their configuration has been defined on paper; to understand the endurance of teeth under abrasive wear when made of wrought or cast iron, brass or steel; how patterns can be constructed from which correct wheels may be cast, and how the teeth of wheels can be cut by machinery, and so on.

The learner should, in fact, consider the application and operative conditions of gearing as the main part of the subject, and the geometry and construction of wheels as subsidiary, and based upon the operation of wheels.

Gearing consists of spur wheels, bevel wheels, tangent wheels, spiral wheels and chain wheels; the last I include among gearing because the nature of their operation is analogous to tooth wheels, although at first thought such chains seem to correspond to belts.

The motion imparted by chains that mesh over the teeth of wheels is positive, and not frictional as in belts. The speed at which gear chains may run, with other conditions, corresponds to gearing.

Tangent wheels as a name is certainly as applicable, and to be preferred to worm wheels, for the class of gearing to which it belongs. As all these forms of gearing can be seen in almost any engineering establishment, and in view of the amount of scientific information relating to wheels that is available to the apprentice, it will only be necessary here to point out some of the conditions that govern the use and operation of wheels.

The durability of gearing, aside from breaking, is dependent upon the amount of rubbing action that takes place between the teeth when in contact; spur wheels or bevel wheels, when the pitch is accurate and the teeth of the proper form, if kept clean and lubricated, wear but little, because the contact between the teeth is that of rolling instead of sliding.

Tangent wheels and spiral gearing have only what is termed line contact between the bearing surfaces, and as the action is a sliding one, such wheels are subject to rapid wear and are incapable of sustaining much pressure, or transmitting a great amount of power, except the surfaces be hard and lubrication constant.

In spiral gearing the line of force is at an angle of forty-five degrees, with the bearing faces of the teeth and the sliding movement equal to the speed of the wheels at their periphery; the bearing on the teeth, as before said, is one of line contact only; such wheels cannot be employed except in cases where an inconsiderable force is to be transmitted.

For communicating movement to the beds of planing machines, or to racks of any kind, the rack can be drawn to the wheel and a lifting action avoided by shortening the pitch of the rack, so that it will vary a little from the driving wheel; the rising or entering teeth in this case do not come in contact with those on the rack until they have attained a position normal to the rack.

### Hydraulic Apparatus for Transmitting Power.

Although a system but recently invented, the use of hydraulic machinery for transmitting and applying power has reached an extended application to a variety of purposes, and gives promise of a still more extended use in future.

Considered as a means of transmitting regularly a constant amount of power, water apparatus is more expensive and inferior in every respect to belts or shafts, and its use must be traced to some special principles involved that adapt hydraulic apparatus for the performance of certain duties.

These principles will be found to consist in storing up power in such a manner that it may be used with great force at intervals, and, secondly, in the facilities afforded for multiplying motion or force by the use of pumps.

An engine of ten horse-power, that is connected with machinery by hydraulic apparatus, may exert a force equal to one hundred horse-

power for one tenth of the time, the power being stored up by accumulators in the interval, or, in other words, the motive power acting continuously can be accumulated or stored up and applied at intervals as it may be required for raising weights, operating punches, compressive forging, or other work of an intermittent character. Hydraulic machinery employed for such purposes is more simple and inexpensive than gearing and shafts, especially in the application of a great force acting for a considerable distance, and where a cylinder and piston represent an amount of strength that could not be gained with twice the amount of detail if screws, levers, or other devices were employed instead.

Motion or power is varied to almost any degree by the ratio between the pistons of the pumps and the pistons that give off the power; the same general arrangement of machinery answering in all cases, whereas with gearing the quantity of machinery has to be increased as the difference between the motive power and the applied power increases; this recommends hydraulic apparatus where a great force is required at intervals, and it is in such cases that it was first applied, and is yet for the most part used. In the use of hydraulic apparatus for transmitting and applying power there is, however, this difficulty to be contended with: water is inelastic and non-yielding, and, in the ordinary machinery for performing irregular duty, there is a loss of power equal to the difference between what a piston can perform and what it does perform, that is, the amount of water, and consequently the amount of power given off, is as the movement, instead of as the work that is performed. This applies to cases where accumulators that store up the power by lifting weights, are used but not to accumulators where the power is stored by compressing air, or in cases where steam pressure acts directly against the water that performs the work; in such cases the consumption of steam is in proportion to the amount of force employed. In the latter case the water in its relations to the motive power and the work is the same as shafts or gearing, merely a medium of regular transmission, The application of hydraulic force to the lifting and handling of weights will be noticed under another head.

### Pneumatic Machinery for Transmitting Power.

Pneumatic machinery, aside from the subtlety and elasticity of air as compared with water, is analogous in operation to hydraulic machinery.

Water may be considered as a rigid medium for transmitting power, and air as a flexible or yielding one, the first corresponding in some respects to gearing and the latter to belts.

There is at this time but a limited use of pneumatic apparatus for transmitting power, but its application is rapidly extending, especially in the way of transporting materials by means of air current and in conveying power to mining machinery.

The successful application of the pneumatic system at the Mont Cenis tunnel in Italy, and at the Hoosac tunnel in America, has demonstrated its value in such operations, where the air not only serves to transmit power to operate the machinery but to ventilate the mines at the same time.

Pneumatic force is also used for sinking foundations, and in some cases for lifts and hoists. Presuming that the flow of air in pipes is not materially impeded by friction or angles, and that there will be no difficulty in maintaining lubrication in pistons or other machinery driven by air, there seems to be many reasons in favor of its use as a means of distributing power in manufacturing districts.

The diminished cost of power when generated on a large scale, and the expense and danger of maintaining a steam power for each establishment, especially in cities, points to many advantages in generating and distributing power as gas and water are now supplied.

Air seems to be the most natural and available medium for transmitting and distributing power upon any general system like water or gas, and there is every probability of such a system existing at some future time. There is no subject more interesting, and perhaps none more important for an engineering student to study at this time, than the transmission of power and transport of material by pneumatic means. The power given out by the expansion of air is not equal to the power consumed in compressing it, but the loss is but insignificant compared with the advantages that may be gained by its use in many cases.

In considering pneumatic machinery there are the following points to which the attention of the apprentice is directed:

The value of pneumatic apparatus in reaching places where steam furnaces cannot be used.

The use that may be made of the exhausted air after it has been applied as a motive agent.

The saving from condensation, to which steam is exposed, avoidance of heat, and the consequent contraction and expansion of conducting pipes.

The loss of power by friction and angles in the flow of air through pipes when carried to long distances.

The lubrication of surfaces working under air pressure, such as the pistons and valves of engines.

The diminished cost of generating power, on a large scale, compared with a number of separate steam engines distributed over manufacturing districts.

The effect of pneumatic machinery in reducing insurance rates and dangers of fire, as compared with steam machinery.

The investment in the appliances of distribution and their maintenance.

In passing thus rapidly over so important a subject, and one that admits so extended a consideration as machinery of transmission, the reader can see that the purpose has been to touch only upon such points as will lead to thought and investigation, and especially to meet the queries that arise in the mind of a learner.

In arranging and erecting machinery of transmission, obviously the first problem must be, what kind of machinery should be employed? And, secondly, what are the conditions that should determine the selection and arrangemeut? What has been written has, so far as possible, been directed to the proper means of solving these questions.

### Machinery of Application.

The term application, has been selected as a proper one to distinguish machines that expend and apply power from those that are employed in generating or transmitting power. Machines of application expend their action on material, and are directed to certain operations, which I will term processes, such as cutting, compressing, grinding, separating and disintegrating.

By classifying these processes, it will be seen that, after all, but a few functions are to be performed by machines, and that they all act upon a few general principles.

For instance, all engineering tools used in fitting are directed to the process of cutting. Planing machines, lathes, drilling machines, and shaping machines are all cutting machines, acting upon the same general principles.

Confining what is said, for the present, to machines of application that have cutting action, it may be assumed that the operation of such machines is governed by certain principles or laws, and that the most thorough manner of studying and understanding the nature

operation and best mode of their operation, manner of constructing such machines, is by a study of these laws or principles.

Cutting, as an operation, includes the force to propel cutting edges, and means to guide and control their action. In cutting with hand tools, the operator performs these functions of propelling and guiding the tools with his hands, and in power operations the machines do the same; but to be of value, machines must either employ more force than a man can exert, or must guide the tools with greater accuracy than is attainable by hand.

Increased speed may also be an object in the employment of machinery, as well as the guidance of cutting edges, or increased force in propelling them; in other words, the hands of an operator are not only limited as to the power that may be exerted, but also as to the rate of movement, which becomes a highly important consideration in many operations where neither the force or guidance of tools are wanting.

There is nothing more interesting, nor at the same time more useful, in the whole study of mechanics, than to analyze the action of cutting machines or other machinery of application, to ascertain whether the main object of a machine is increased force, more accurate guidance, or greater speed than is attainable by hand operations. Cutting machines may be directed to either of these objects singly, or to all of them together, or these objects may vary in their relative importance in different operations, but in all cases the general principles remain the same.

To follow this matter further, we find in such machines as are directed mainly to augmenting force or increasing the amount of power that may be applied to any operation, such as sawing wood or stone, the effect produced when compared to hand labor, is nearly as the difference in the power applied, and the saving that such machines effect is generally in the same proportion. A machine that can expend ten horse-power in performing its work, will save ten times as much as a machine that expends but one horse-power, provided the purpose of the machine is to perform operations in which hand labor lacks power.

In other machines of application, where they are directed mainly to guidance or speed of action, such as sewing machines, dove-tailing machines, gear cutting machines, and so on, there is no relation whatever between the advantages gained and the amount of power expended.

The difference between hand and machine operations and the labor saving effect of machines, will be treated in another place; the subject is alluded to here, only to enable the reader to more fully distinguish between machinery of transmission and machinery of application.

Machinery of application directed to what has been termed compression processes, such as steam hammers, drops, presses, rolling mills, and so on, act upon material that is naturally soft and ductile, or when it is softened by heat, as in the case of forging.

The nature of compressive operations of all kinds is distinguished from cutting and abrading, in the fact that no material is cut away, the mass being forced into shape by dies or forms that give the required configuration.

The action of compressing machines may be either intermittent, as in the case of rolling iron, or percussive, as in steam hammers, where a great force acts throughout a limited distance.

Machines for abrading or grinding are common among machinery of application, their main purpose being to cut or shape material that cannot be heated, and is too hard to be acted upon by compression or by cutting processes.

Separating machines, although forming a distinct class, such as bolting and screening machines for grain, are not complex enough to require explanation.

Grinding, no doubt, if traced to the principles that lie at the bottom, is nothing more than a cutting process, in which the edges employed are harder than any material that can be made into cutters, and in which these edges are firmly supported by being imbedded into a mass like the particles of sand in grindstones, or the particles of emery in emery wheels.

Disintegrating machinery, as a class, includes machines directed to grinding grain, or separating the fibres of textile material, such as grinding mills, pulp machines, cotton and wool machinery.

The principle of action in machines of this class requires no special explanation here; the process is one of crushing, tearing and macerating.

To be continued.

## METHOD OF ASCERTAINING WHAT PORTION OF THE FEED-WATER ADMITTED TO A BOILER IS ENTRAINED IN THE FORM OF SPRAY BY THE ESCAPING STEAM.

By Chief Engineer Isherwood, U. S. Navy.

In making tests of the evaporative efficiency of boilers, it is desirable to know what fraction of the feed-water admitted to the boiler during an experiment is vaporized, and what fraction in the form of spray is mingled with and entrained by the steam.

This problem is very difficult to solve correctly, requiring costly apparatus; precise measurements of large quantities of water; thermometers absolutely accurate, for a very slight error in the temperatures would be equivalent to a very considerable error in the two fractions of the feed-water to be ascertained; and boilers perfectly free of leakage under the pressure employed.

The apparatus needed is a tank for the measurement of the feed-water previous to admission in the boiler; a condenser, in which all the steam generated in the boiler is condensed, and the temperature of the resulting water together with that of the water entrained in the form of spray, is reduced to the temperature of the feed-water; and a tank for the measurement of the condensing water previous to its use in the condenser. The condenser and the steam-pipe connecting it with the boiler, are to be covered with felt or other non-conducting substance, and placed in a temperature midway between that of the steam and that of the condensing water after use, as any heat lost or received by the steam and entrained water after leaving the boiler, would vitiate the results. Placing the condenser and steam-pipe in a temperature midway between that of the steam entering and that of the condensing water leaving the condenser, neutralizes, as nearly as possible, the effect of external temperature; and clothing them, additionally, with a non-conducting substance, reduces this effect to a minimum.

The pressure under which the generation and condensation of the steam take place must be identical, and the initial temperature of the feed-water must also be identical with the final temperature of the condensing water, in order to eliminate the transformation of heat into work which would otherwise be caused by the displacement of different pressures, due to the difference of bulks resulting from the difference of temperatures.

The principle of the investigation is simply a comparison of the quantity of heat that would have been imparted to the feed-water in the boiler, had all the feed-water been vaporized, with the quantity of heat (experimentally ascertained) imparted to the condensing water by the condensation of the steam and the reduction of the temperature of the resulting water, together with that of any water which may have been entrained in the form of spray, to the initial temperature of the feed-water.

Let w be the weight of feed-water admitted to the boiler;

$t^o$, the temperature of the feed-water;

$t_1^o$, the temperature of the steam; and

h, the heat of vaporization above the temperature $t^o$. Also,

let W be the weight of condensing water used;

$T^o$, the temperature of the condensing water before use; and

$T_1^o$, the temperature of the condensing water after use. Finally,

let $w_1$ be the weight of feed-water in the form of spray, having the temperature $t_1^o$ entrained by the steam; then

$w - w_1$ is the weight of feed-water vaporized.

And $(w - w_1) \times h + w_1 \times (t_1^o - t^o) = W \times (T_1^o - T^o)$.

$W \times (T_1^o - T^o)$ represents the total quantity of heat, experimentally ascertained, imparted to the feed-water in the boiler, which quantity is composed of the unknown quantity $(w - w_1) \times h$, consumed in vaporizing the weight $w - w_1$ of feed-water, and of the unknown quantity $w_1 \times (t_1^o - t^o)$, consumed in raising the temperature of the weight $w_1$ of feed-water from $t^o$ to $t_1^o$. The determination of the valves of $w_1$ and of $w - w_1$ in fractions of w is the object of the following process.

The specific heat of the water is supposed to be constant at all its temperatures, which is not quite true; the correction, however, would be so insignificant that it has been omitted, to avoid unnecessary complication. It can be easily made, if required, by simply multiplying the weights of water at the different temperatures by the respective specific heats and taking the products as the weights in place of the original weights of water.

It is obvious that the quantity $W \times (T_1^o - T^o)$, as experimentally found, will equal $w \times h$ in the case in which all the feed-water is vaporized. It can never be greater than $w \times h$, but may easily be

less by the entrainment of part of the feed-water with the steam, and less in proportion as the quantity so entrained is greater. This results from the fact that the heat of vaporization of a given weight of feed-water is much greater than that which is required to raise its temperature from $t^\circ$ to $\overset{1}{t}{}^\circ$.

In the single case in which the temperature of the feed-water is the same as that of the steam entraining a portion of it in the form of spray, the fraction vaporized of the feed-water is the fraction which the experimental quantity $W \times (\overset{1}{T}{}^\circ - T^\circ)$ is of the quantity $w \times h$; that is, this fraction will be the quotient of $\frac{W \times (\overset{1}{T}{}^\circ - T^\circ)}{w \times h}$, the remaining fraction of the feed-water having been entrained in the form of spray, but, not having had any heat imparted to it in the boiler, does not enter as a factor in the computation. For example: Suppose the temperature $t^\circ$ of the feed-water and $\overset{1}{t}{}^\circ$ of the steam to be 212° Fahrenheit; the heat h of vaporization, 965·7 Fahrenheit units; the weight w of the feed-water admitted to the boiler, 1 pound; the weight W of condensing water, 5 pounds; the temperature $T^\circ$ of the condensing water before use, 50° Fahrenheit; and its temperature $\overset{1}{T}{}^\circ$ after use, 212° Fahrenheit. Then $\frac{5 \times (212° - 50°)}{1 \times 965{\cdot}7} = 0{\cdot}83877$ = the fraction vaporized of the feed water, while the fraction entrained in the form of spray by the steam is (1·00000—0·83877=) 0·16123.

But in all other cases of the entrainment of feed-water, in which its temperature is less than that of the steam, the experimental quantity of heat $W \times (\overset{1}{T}{}^\circ - T^\circ)$ is composed of two unknown quantities $\overset{1}{w} \times (\overset{1}{t}{}^\circ - t^\circ)$ and $(w - \overset{1}{w}) \times h$, the first being the quantity of heat imparted to the entrained water, and the last being the quantity of heat imparted to the vaporized water. Hence, considering the entire weight w of feed-water admitted to the boiler as unity,

$$\frac{(w \times h) - W \times (\overset{1}{T}{}^\circ - T^\circ)}{h - (\overset{1}{t}{}^\circ - t^\circ)} = \overset{1}{w} = \text{the fraction of the entire feed-water admitted to the boiler, which has been entrained in the form of spray by the steam.}$$

Consequently, $w - \overset{1}{w} = 1 - \overset{1}{w}$ = the fraction of the entire feed-water admitted to the boiler, which has been vaporized.

From the above formula may be derived the following rule for ascertaining the proposed results: From the quantity of heat which would have been imparted to the feed-water admitted to the boiler, had it *all* been vaporized, deduct the quantity of heat which was imparted as experimentally given by the increased temperature of the weight of condensing water used, and divide the remainder by the latent heat of the steam; the quotient will be the portion, in terms of the unit of weight employed, of the feed-water entrained in the form of spray by the steam. The subtraction of this quotient from the weight of feed-water admitted to the boiler gives the portion, in terms of the unit of weight employed, of the feed-water vaporized.

The above formula is based on the following reasoning: $w \times h$ is the quantity of heat that would have been imparted to the feed-water had it all been vaporized. $W \times (T^{1\circ} - T^{\circ})$ is the quantity of heat that was imparted to the feed-water as experimentally ascertained. The latter quantity subtracted from the former leaves the quantity of heat due to the non-vaporization of a portion of the feed-water, which had been heated, however, to the temperature of the steam. The division of this remainder by the latent heat of the steam gives the weight of water, in terms of the unit employed, which was not vaporized, and which, consequently, was entrained in the form of spray by the escaping steam. The expression $h' - (t^{1\circ} - t^{\circ})$ is the latent heat of the steam. The following is a numerical application of the formula:

Suppose, for example, the entire weight w of feed-water admitted to the boiler to be 1 pound; the heat h of vaporization above the temperature $t^{\circ}$ of the feed-water to be 1078·5 Fahrenheit units; the weight W of the condensing water to be 19·637 pounds; the temperature $T^{\circ}$ of the condensing water before use to be 50° Fahrenheit; and its temperatue $T^{1\circ}$ after use to be 100° Fahrenheit; the temperature $t^{\circ}$ of feed-water to be 100° Fahrenheit; and the temperature $t^{1\circ}$ of the steam to be 212° Fahrenheit. Then

$$\frac{(1 \times 1078.5) - 19.637 \times (100° - 50°)}{1078·5 - (212° - 100°)} = 0·1 = \text{the fraction of the entire feed-water admitted to the boiler which has been entrained in the form of spray by the escaping steam. Consequently } 1 - 0·1 = 0·9 = \text{the fraction of the entire feed-water admitted to the boiler which has been vaporized.}$$

## GIRARD AVENUE BRIDGE.

By R. Hering, C. E. Assistant Engineer in charge, and T. C. Clarke, C. E.

This bridge which is now under process of construction by the firm of Clarke, Reeves & Co., for the City of Philadelphia, was put under contract one year ago to-day, and is to be completed on the 22d September, 1874.

It crosses the Schuylkill river on the line of Girard Avenue, and will always be the chief entrance to the West Park, and during the Centennial Exhibition it will be the principal avenue of approach to the buildings.

Under these circumstances, it was considered that its dimensions should be ample, and that in solidity of construction, and in elegance of decoration, it should be surpassed by none.

Its principal dimensions are as follows:

| | |
|---|---|
| Total length, | 1,000 feet. |
| " width, | 100 " |
| Number and size of spans, | 2 of 137, and 3 of 197 " |
| Length of side walk, | 865 " |
| Number of piers, 4, abutments, 2 | |
| Width of roadway, | 67½ " |
| " " each side walk, | 16½ " |
| Greatest height from roadway to rock foundation | 85 " |
| Number of square feet of surface, | 100,000 " |
| Cost per foot, | $14 86. |

*Foundations.*—The foundations of this bridge are constructed according to that system, first applied in this country on a large scale to bridge foundations at the Mississippi bridge at Quincy. That is to say, instead of pumping out the water by coffer-dams, or forcing it out by the use of compressed air, the water is not removed, but the material is dredged out, and when the rock is laid bare, it is covered with concrete, lowered through the water in an iron box, specially contrived to deposit it without washing out the cement. All the foundations were put in in this way, except that of the eastern pier, which was put in by a coffer-dam, and pumped out in the usual way. This was done in this special case, on account of the foundation being upon the site of an old timber and stone wharf which could not have been easily removed under water.

The foundation of the western shore pier was enclosed by a dam of 12 × 12″ sheet piling, driven to the rock. The clay was then removed

by a dredge shaped like a pair of clam-shells, and finally cleaned by the rotary pump, and the concrete laid on the bare rock.

The foundations of the two central piers were formed by sinking a double-walled bottomless caisson, 34 feet wide × 156 feet long, down upon the rock, which was first cleaned by dredging and divers. The spaces between the sides were filled with rough stone. The interior space was then cleaned by divers, using a rotary pump, which sucked up all the soft material, leaving the rock bare. The concrete was then lowered down, and its upper surface levelled off 18 feet below water. The masonry was then built and sank in an ordinary water-tight caisson.

Not the slightest sign of settlement or cracking has shown itself. The concrete moulds itself when soft to the irregularities of the rock bottom and hardens into a monolith, so that settlement is impossible if the concrete has been properly made. In the present case, the load thrown upon the concrete when new does not exceed 30 lbs. per square inch, and it is capable of resisting 300 lbs per square inch.

The materials employed were: Portland, Rosendale, Coplay, Allen, and Old Lehigh Cements, sharp river sand, coarse, screened gravel, and broken furnace slag. Of these, seventeen samples, each of a different proportion, were carefully mixed and kept under water 30 days. After that time they were tested with the following results:

The Rosendale cement had entirely failed, perhaps on account of its not being fresh when used. Its qualities have lately been very unreliable, and it was therefore rejected. The Portland cement, as was expected, acted by far as the best. The Coplay and Old Lehigh showed nearly equal strength, and the Allen gave the weakest specimen. Later, more careful comparisons between the Coplay and Old Lehigh cements proved that the former was somewhat the strongest, and much quicker in setting, therefore best adapted for subaqueous work.

Further, nearly all samples containing gravel, which held a considerable amount of loam adhering to it, broke with an entirely insufficient weight, and this material was therefore also rejected.

The furnace slag, crushed to pass through a 2 inch mesh, proved highly satisfactory. Its hardness, its rough texture, the angular form of each piece, seem to make it well suited for the intended purpose. All samples prepared with it and an amount of cement mortar sufficient to fill the interstices were entirely satisfactory.

The Portland cement allowed over twice the quantity of sand and

slag to be mixed with it, to give the same strength as the Coplay cement.

It was also found that the proportion of voids to solid naterial in the broken slag, was exactly as 1 : 2.

From these results the following materials and proportions were selected :

$$1 \begin{cases} 1 \text{ part Coplay Anchor cement.} \\ 1 \text{ " sharp river sand.} \end{cases}$$
$$2 \begin{cases} 4 \text{ " furnace slag.} \end{cases}$$

The strength of this concrete was 308 lbs per square inch, after 30 days insertion in water. The extreme pressure per square inch on the foundation from bridge and heaviest load, will not be over 45 lbs.; we may therefore feel assured of its efficiency.

The concrete was mixed by hand on platforms, until each stone seemed to be coated with mortar, and was then lowered in a box, so contrived as to protect it from wash during its descent, and easily discharge it when touching bottom.

*Masonry.*—The masonry of the four piers is made of granite from the Maine quarries of Blue Hill and Buck's Harbor, from which came the granite for the piers of Saint Louis' bridge, and a portion of that for Brooklyn bridge.

It is a hard stone, of a rather light color and medium grain, the Buck's Harbor being the coarser of the two.

The abutments are made of Port Deposit granite, with quoins of a darker stone from the Bellevieu quarries on the line of the Philadelphia and Baltimore Railway. The copings and parapets are of fine cut granite from Blue Hill quarries.

The specifications under which this masonry was constructed were as follows :

" The quoins shall be of dimension stone in courses from 16 to 32 inches high, heaviest at bottom and diminishing gradually towards top. They will be cut with a rock or quarry face and have 1″ chisel draft, and chamfers 1½″ wide × 1″ deep on the horizontal and vertical end joints, and will project 2″ beyond face of wall ; will also have chisel draft 1½″ wide down each side of nose. They will be clamped with ¾″ round bars covered with coal tar to above high-water mark.

" The side walls between end quoins shall be built of quarry-faced ashlar, pitched to the proper lines. Courses same height as quoins. Headers not less than one and a half times the depth of course for face length, and depth in wall double face length. There shall be one

header to every two stretchers. Stretchers from four to seven feet long, and as much bed as rise. All stones to be sound and free from imperfections, to be dressed true and parallel on beds, so as to lay to a $\frac{3}{8}$" joint. Vertical joints to be square with face for six inches back. Courses should bond on those below, a distance generally not less than depth of course, and in no case less than 12 inches.

"Backing either of concrete or suitable stone, not over two courses of backing to one of face. All face stone must be laid by tackle and lewis, and in mortar composed of one part of fresh ground Lehigh cement to two parts clean sharp sand.

"When directed, the joints shall be picked out, and properly pointed in cement with a rounded tool."

*Superstructure.*—The form adopted for the superstructure is the quadrangular girder, as usually made at Phœnixville. The upper chords and posts are Phœnix columns, united by cast-iron joint blocks. The lower chords and diagonal bars are Phœnix weldless eye bars. There are seven trusses, placed side by side, 16 ft. apart, and united by horizontal bracing. Upon them are laid heavy 15-inch Phœnix rolled beams, and upon these are laid longitudinally 9-inch rolled beams, placed 2′ 8″ apart. These will be crossed again transversely by rolled iron plates $\frac{1}{4}$ of an inch thick, corrugated $1\frac{1}{4}$ inches deep by 5 inches wide, as per specimen submitted.

The bridge and moving load of 100 pounds per square foot makes a total load of 30,000 pounds per lineal foot carried by seven trusses, equal to 4,286 pounds per lineal foot on each, or about three times that of an ordinary railway truss of similar span.

The limit of strain is ten thousand pounds per square inch of section, reduced to 6,000 pounds as compressive limit of posts, and 7,500 pounds shearing strain on pins.

All the points of contact are turned or planed, and the limit of error is $\frac{1}{64}$ of an inch. The iron is double refined, or Phœnix "Best Best," capable of bearing the regular tests as follows:

| | |
|---|---|
| Ultimate strength, . . . . | 55,000 to 60,000 lbs. per □" |
| No permanent set under, . . | 25,000 to 30,000 " " |
| Average reduction of area at heating, | 25 per cent. |
| Elongation of bar, . . . . | 12″ long, 15 per cent. |
| Cold bend, . . . . | 180° |

The whole bridge is on a regular camber of 18 inches, and the east end is 2 feet higher than the west end.

Considerable discussion took place at the time of awarding the con-

tracts for the construction of this bridge, as to the relative merits of iron arches and girders with parallel top and bottom members. The public eye has been educated to delight in the graceful curves of an arch, and it was with some reluctance that this form was given up.

For a stone bridge there can be no doubt but that the arch is both constructively and æsthetically correct. For an iron bridge it is not constructively correct in this climate of extreme variations of temperature, which would throw strains of more than double those resulting from the changes of temperature of the more even climate of Europe.

What the Arabian proverb says of stone construction is peculiarly applicable to an iron arch—"The arch never sleeps."

It is true that all these evil effects can be prevented by dividing the arch into two parts, and hinging it at the centre, and at each point of springing. But this is reducing the depth at the centre to nothing, and the arch, although perhaps strong enough, is not stiff, and will vibrate under a passing load.

As the authorities did not wish to be under the necessity of putting up a sign, "No trotting allowed on this bridge," they preferred to abandon the idea of arches and use parallel girders, whose stiffness is undoubted.

As you well know, expansion is provided for in girders by fixing one end to the pier and placing the other on rollers, leaving it free to move without causing any strain on the iron. In order that this movement might not interfere with the permanence of the roadway, the longitudinal beams are not attached to the floor beams upon which they rest, so that the main girders expand and contract independently of the floor system. The longitudinal beams are "fished" together with oval-holed plates, like a railway track, so that the movement is not accumulative. Upon these beams are laid, but not fastened, the corrugated iron floor plates.

These plates will be covered with asphalt concrete, so as to form a perfectly water-tight surface over the whole bridge. Upon this will be laid sand, and then granite blocks, forming the usual Belgian pavement, such as is used on Market and Broad streets, except that it will be divided into seven roadways by as many double lines of tram-ways, made of cut granite stones one foot wide and laid five feet apart.

These will not be sufficiently raised above the general surface of the pavement to interfere with crossing diagonally or "turning out,"

but being smoother than the rest can be made, will allow teams to glide over the bridge with the least possible noise and vibration.

The gutters and curb stones on either side will be of fine cut granite.

The sidewalks will have ten feet of their width made of black Lehigh county slates, laid in diagonal squares about 2 ft. × 2 ft. On each side there will be a row of bright borders, made of Maw & Co.'s encaustic tiles. Inside will be the curb stone 18″ wide.

The sidewalks will be divided from the roadways by railings of galvanized iron tubes with bronze ornaments, supported by cast-iron standards every six feet. At about every forty-eight feet the standard will be prolonged into a lamp post. On each of the eight refuge bags there will be clusters of lamps, treated in a highly ornamental manner.

There will be an outer balustrade and cornice of a highly ornamental design, containing panels of bronze, designed to represent birds and foliage. There will be about ten different patterns, arranged so that they will be repeated not oftener than sixty feet apart. There will be about a third of a mile of these bronzes set in the balustrade like pictures in a frame.

The whole treatment of this part of the bridge is believed to be original and different from any existing structure. It will form one of the contributions to the Centennial Exhibition of 1876 of the city of Philadelphia, and will probably be seen and criticised by the highest artistic knowledge in the world.

*Architectural Decoration.*—Great public works have been executed in all ages of the world, but it was not until the early part of the last century that their builders were divided into two distinct professions, called architects and civil engineers. At this time the line of division is very marked, and the results of this separation have, in many instances, not been productive of happy results from an artistic point of view.

Architecture has been well defined to be the art of decorative and decorated construction, that is to say, grace embodied in the structural contrivance, and grace superadded in the shape of ornament.

There can be no satisfactory architecture without both of these things. The first is indispensable; for unless the lines and proportions of the structures are good, no amount or richness of ornament can make it pleasing. On the other hand, the pleasing effect of good proportion and outline can be seriously marred by the injudicious application of ornament.

Engineering proper deals only with construction. It often happens

that an engineer will design a bridge, for example, to be built in some inaccessible place on a line of railway, and he will think ornament a useless expense. The subtle laws which govern the proportions of bodies placed to resist static forces will govern the shapes, and mould them in such a way that the plain, unadorned structure is pleasing to the eye of taste.

The same engineer, however, having another bridge to build, will think it necessary that it should be ornamented. Not understanding the true principles of decoration, he will cover his structure with sham arcades, and hang up rows of impossible pilasters resting on nothing.

Recognizing the danger of falling into this mistake, the designers of Girard Bridge have called into counsel the aid of professionally educated architects, the Messrs. Sims, members of the American Institute of Architects.

In designing the purely decorative features of this bridge, these gentlemen have been guided by the following principles:

1st. That there should be no sham ornamentation, no concealment of parts, and no effort to make one thing look like another. The ornament is merely an emphasizing or accentuating the prominent lines of construction.

2d. Each kind of material is allowed to suggest for itself its appropriate treatment, so as to show what it is. For example, iron is made to look like iron, and not like stone or wood.

3d. Color will be relied on to do what nature uses it for—to distinguish parts from one another.

Thirteen months have passed since this bridge was put under contract, and eleven since construction began. During this time a temporary bridge, 1050 feet long and 50 feet high, has been built; the foundations and masonry of the permanent structure have been completed, and the iron work has been made and erected.

It now only remains to complete the roadway, and it is hoped that this will be done in time to open the bridge for traffic several months before the date for completion of September 21, fixed in the contract.

When it is considered that this structure, although less than a quarter of mile long, contains as much material as is in a mile and a half of single track railroad bridge of similar spans, we can at least say that there has been no unnecessary delay so far.

The general dimensions of this bridge and the character of its materials were fixed by Samuel L. Smedley, Esq., Chief Engineer of the city of Philadelphia, under whose superintendence the whole works have been carried out.

## RAILWAY CROSSINGS AND TURNOUTS.

By C. A. Evans, Civil Engineer.

Laying switches on railroads has, at present, to a very great extent, passed out of the hands of the engineer into those of the track master. The reason for this change is a simple one. The track master can, by his eye and a little experience, put down a switch, over which a train will pass apparently with ease, thus seeming to dispense with the mathematical data of the engineer. This is a bad practice, notwithstanding its universality; for, necessarily, the switch of the track master will be irregularly curved. It will therefore wear unequally, and finally be worn out at some point, often at the frog, before it has performed the full duty which a regular curvature would ensure. In a large yard, where there is much drilling and a heavy wear and tear in consequence, good switches are a matter of importance.

With a view to aid the engineer in laying out his switches quickly and with little calculation, whether on a straight line or on a curve, tables are here appended for this purpose. The formulæ by which these tables have been calculated are more numerous than those usually given in field books. This difference is owing to improvements in the arrangement of switches. Improvements have, in this case, as in many others, complicated the work. As it would not be proper to give the tables without the formulæ, the author will now proceed to establish these. It is preferable to treat separately the case of switches on straight lines from that of switches on curves, although the formulæ of the former may be deduced from those of the latter. Throughout the following investigations we will employ this notation, viz.:

$g$ = gauge of tracks.

$d$ = throw of switch rail.

$l$ and $l^1$ = tangents passing through the point of the frog.

$b$ = distance between tracks, including widths of both rails.

R and $R_1$ = radii of the centre line of the switch.

X = distance from point of frog to end of switch on the first branch.

Y = distance from the same to the other end of switch, measured on the same rail, on the second branch.

S = switch angle.

F = frog angle.

The problem of crossings and turnouts to parallel tracks presents

itself in the following form: Given the frog angle, F, to find the distances, X and Y, the radii, R and $R_1$; and on curves, the other frog angle $F^1$. Commencing with the *crossing on a straight track*, we have from Fig. 1:—

$$\overline{B\,F} = 2\,(R + \tfrac{1}{2}\,g)\sin\tfrac{1}{2}\,(F - S) = \frac{g - d - l\sin F}{\sin\tfrac{1}{2}\,(F + S)}$$

Therefore, we have, to obtain R:—

$$R + \tfrac{1}{2}\,g = \frac{\tfrac{1}{2}\,(g - d - l\sin F)}{\sin\tfrac{1}{2}\,(F - S)\,\sin\tfrac{1}{2}\,(F + S)} = \frac{g - d - l\sin F}{\cos S - \cos F} \quad (1)$$

For X we have:—

$$X = \frac{g - d - l\sin F}{\tan\tfrac{1}{2}\,(F + S)} + l\cos F. \quad (2)$$

We have from the triangle $\overline{G\,Q\,I}$ and the sector $\overline{P\,E\,G}$:

$$l^1\sin F = b - d - (R - \tfrac{1}{2}\,g)\,(\cos S - \cos F.)$$

Hence:

$$l^1 = \frac{b - d - (R - \tfrac{1}{2}\,g)\,(\cos S - \cos F)}{\sin F} = \frac{b - d}{\sin F} =$$

$$\frac{2\,(R - \tfrac{1}{2}\,g)\sin\tfrac{1}{2}\,(F - S)\sin\tfrac{1}{2}\,(F + S)}{\sin F.} \quad (3)$$

The value of $R_1$ is evidently equal to that of R.

We will now consider the *turnout on a straight track*. In this case we employ for the first branch eqs. (1) and (2), then assume, if desired, the value of *l*, and proceed to calculate the radius $R_1$ and the distance Y. For this last purpose substitute in eqs. (1) and (2):

$$R + \tfrac{1}{2}\,g = R_1 - \tfrac{1}{2}\,g,\ l = l^1,\ g = b^1,\ S = o,\ d = o,$$

and we have:

$$R_1 - \tfrac{1}{2}\,g = \frac{b^1 - l^1\sin F}{2\sin^2\tfrac{1}{2}\,F} = \frac{b^1 - l^1\sin F}{1 - \cos F} \quad (4)$$

$$Y = \frac{b^1 - l^1\sin F}{\tan\tfrac{1}{2}\,F} + l^1\cos F. \quad (5)$$

Next in order comes the consideration of the *crossing on a curved track*. Whether the switch turns to the inside or outside of the curve is a matter of indifference, as the values of the unknowns are independent of the direction of the switch on the curve. In Fig. (2) we will commence with the upper branch. To find the distance X, we need find only the angle:

$$\overline{O\,K\,R} = \overline{O\,K\,F} + \overline{F\,K\,R} = K^1 + K.$$

The first of these angles is obtained from the triangle $\overline{O\,K\,F}$, having given:

$\overline{O\,F} = l$, $\overline{O\,K} = Ro - \frac{1}{2}g$, and the included angle $\overline{K\,O\,F} = 90° + F$

$$\left.\begin{aligned} \text{Therefore, } \tan\tfrac{1}{2}(\overline{K\,F\,O} - K^1) &= \frac{Ro - \frac{1}{2}(g-l)\tan\frac{1}{2}(90°-F)}{Ro - \frac{1}{2}g + l} \\ \text{which with: } \tfrac{1}{2}(\overline{K\,F\,O} + K^1) &= (90° - F) \end{aligned}\right\} \quad (1)$$

gives us also the angle $\overline{K\,F\,O}$.

We may also write: $$\overline{K\,F} = (Ro - \tfrac{1}{2}g - l)\,\frac{\sin\frac{1}{2}(90° - F)}{\sin\frac{1}{2}(\overline{K\,F\,O} - K^1)} \quad (2)$$

Passing now to the triangle $\overline{B\,K\,F}$, we have given:

$$\overline{B\,K} = Ro + \tfrac{1}{2}g - d, \overline{K\,F},$$

and we can deduce expressions for the opposite angles in terms of K and other angles. Thus:

$$\overline{B\,F\,K} = \overline{B\,F\,E} + \overline{E\,F\,K} = S + \overline{K\,B\,F} + 90° - \overline{K\,F\,O}, \overline{K\,B\,F}$$

$$\text{Hence: } \cot\tfrac{1}{2}K = \frac{\tan\frac{1}{2}(S + 90° - \overline{K\,F\,O})\,(Ro + \frac{1}{2}g - d + \overline{K\,F})}{Ro + \frac{1}{2}g - d - \overline{K\,F}} \quad (3)$$

We have therefore: $$X = 2\,(Ro - \tfrac{1}{2}g)\sin\tfrac{1}{2}(K + K^1) \quad (4)$$

Also: $\overline{B\,F\,K} + \overline{K\,B\,F} = S + 2\,\overline{K\,B\,F} + 90° - \overline{K\,F\,O} = 180° - K$,

from which: $\overline{K\,B\,F} = \frac{1}{2}(90° - K - S + \overline{K\,F\,O})$, and, consequently, $$\overline{B\,F} = (Ro + \tfrac{1}{2}g - d - \overline{K\,F})\,\frac{\cos\frac{1}{2}K}{\sin\frac{1}{2}(S + 90° - \overline{K\,F\,O})} \quad (5)$$

Passing next to the isosceles triangle $\overline{E\,B\,F}$, we have:

$$\overline{E\,B\,F} = \overline{K\,B\,F} + S = \tfrac{1}{2}(90° - K + S + \overline{K\,F\,O})$$

which leads to: $$R + \tfrac{1}{2}g = \frac{\frac{1}{2}\overline{B\,F}}{\cos\frac{1}{2}(90° - K + S + \overline{K\,F\,O})} \quad (6)$$

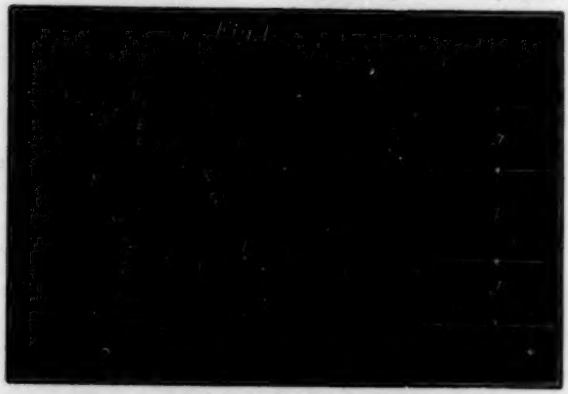
To obtain the value of $l^1$ we have in the triangle $\overline{K\,G\,F}$;

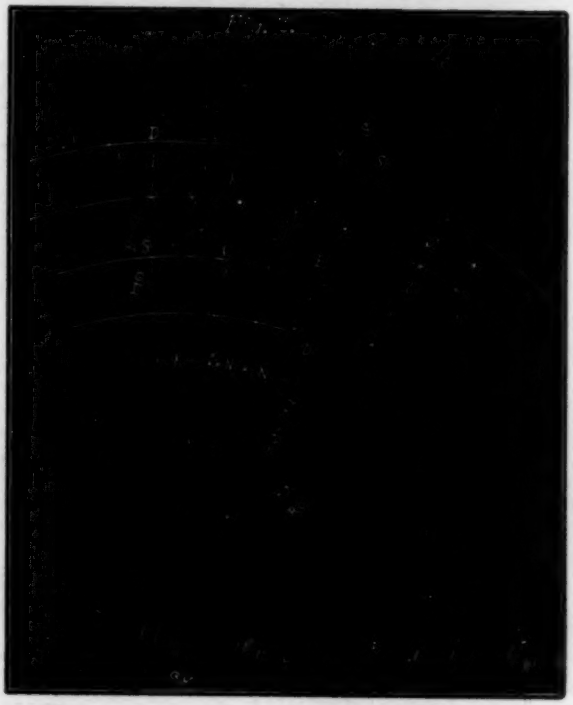
$\overline{G\,F} = g$, $\overline{K\,F}$ as calculated, $\overline{G\,F\,K} = 90° - \overline{K\,F\,O}$,

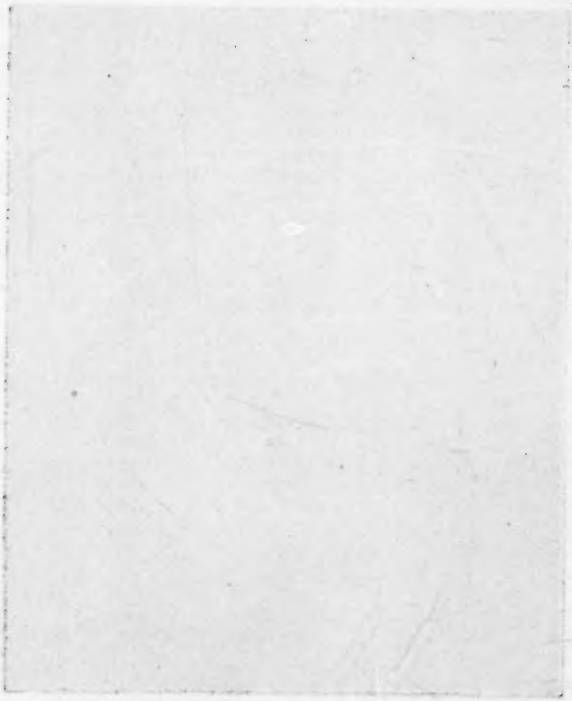
and consequently for the other angles:

$$\left.\begin{aligned} \tan\tfrac{1}{2}(\overline{F\,G\,K} - \overline{G\,K\,F}) &= \frac{(\overline{K\,F} - g)\tan(45° + \frac{1}{2}\overline{K\,F\,O})}{\overline{K\,F} + g} \\ \tfrac{1}{2}(\overline{F\,G\,K} + \overline{G\,K\,F}) &= 45° + \tfrac{1}{2}\overline{K\,F\,O} \end{aligned}\right\} \quad (7)$$

$$\text{Also, } \overline{K\,G} = (\overline{K\,F} - g)\,\frac{\sin(45° + \frac{1}{2}\overline{K\,F\,O})}{\sin\frac{1}{2}(\overline{F\,G\,K} - \overline{G\,K\,F})} \quad (8)$$







## No. 543 Frog (old No. 10), F=5° 43′ 31″.

| | Curvature of track. | X | Y | $l$ | $l'$ | R | $R_1$ | F′=GQK—90° |
|---|---|---|---|---|---|---|---|---|
| | | FT. | FT. | FT | FT. | FT. CURV'RE. | FT. CURV'RE. | ° ′ ″ |
| * | 0° | 56·94 | 82·88 | 5.00 | 31·08 | 960·39= 5° 58′ | 960·39= 5° 58′ | 5 43 31 |
| | 1° | 56·63 | 85·69 | " | 31·67 | 805·64= 7° 07′ | 1481·01= 4° 09′ | 5 28 |
| | 2° | 56·29 | 89 14 | " | 32.36 | 695 09= 8° 15′ | 3473·89= 2° 19′ | 5 11 |
| * | 3° | 55·93 | 93·21 | " | 33·13 | 611·70= 9° 23′ | 11113·12= 0° 31′ | 4 53 53 |
| | 4° | 55·57 | 97·92 | " | 33·99 | 545·59=10° 31′ | -4469·17= 1° 17′ | 4 35 |
| | 5° | 55·19 | 103·27 | " | 34·95 | 491·96=11° 40′ | -1868 79= 3° 04′ | 4 15 |
| * | 6° | 54·81 | 109·25 | " | 36 00 | 448·09=12° 50′ | -1195·97= 4° 48′ | 3 53 47 |

## No. 709 Frog (old No. 8), F=7° 09′ 10″.

| | | FT. | FT. | FT. | FT. | FT. CURV'RE. | FT. CURV'RE | ° ′ ″ |
|---|---|---|---|---|---|---|---|---|
| * | 0° | 47·87 | 68·71 | 5.00 | 26·00 | 542·65=10° 34′ | 542·65=10° 34′ | 7 09 10 |
| | 1° | 47 58 | 70·34 | " | 26·37 | 487·13=11° 47′ | 661·74= 8° 40′ | 6 57 |
| | 2° | 47·30 | 72·17 | " | 26 74 | 442·25=12° 59′ | 849 32= 6° 45′ | 6 44 |
| * | 3° | 47·04 | 74·22 | " | 27·10 | 405·87=14° 10′ | 1177·70= 4° 53′ | 6 30 41 |
| | 4° | 46·80 | 76·48 | " | 27·46 | 374 39=15° 21′ | 1899 76= 3° 01′ | 6 16 |
| | 5° | 46·56 | 78·94 | " | 27·80 | 348·11=16° 31′ | 4911·15= 1° 10′ | 6 02 |
| * | 6° | 46·34 | 81·62 | " | 28·14 | 324·91=17° 40′ | -8781·94= 0° 40′ | 5 48 22 |

## No. 931 Frog (old No. 6), F=9° 31′ 36″.

| | | FT. | FT. | FT. | FT. | FT. CURV'RE. | FT. CURV'RE. | ° ′ ″ |
|---|---|---|---|---|---|---|---|---|
| * | 0° | 37·48 | 53·26 | 5·00 | 20·97 | 269·47=21° 23′ | 269·47=21° 23′ | 9 31 36 |
| | 1° | 37·31 | 53·90 | " | 21·13 | 254·68 | 298 54=19° 17′ | 9 22 |
| | 2° | 37·13 | 54·64 | " | 21·28 | 241·07 | 334·05=17° 13′ | 9 13 |
| * | 3° | 36·97 | 55·48 | " | 21·42 | 228.67 | 378·59=15° 10′ | 9 03 49 |
| | 4° | 36·81 | 56·43 | " | 21·55 | 217·46 | 437·22=13° 08′ | 8 54 |
| | 5° | 36·64 | 57·48 | " | 21·68 | 207·43 | 516 24=11° 07′ | 8 44 |
| * | 6° | 36 48 | 58·64 | " | 21·79 | 198·60 | 627·01= 9° 08′ | 8 34 37 |

In the triangle $\overline{K\,G\,Q}$ we have given :

$$\overline{K\,G},\ \overline{K\,Q} = R_2 + \tfrac{1}{2}\,g,\ \overline{K\,G\,Q} = \overline{F\,G\,K} - 90°.$$

$$\text{Hence : } \sin \overline{G\,Q\,K} = \frac{\sin\,(\overline{F\,G\,K} - 90°)\,\overline{K\,G}}{R_2 + \tfrac{1}{2}\,g} \qquad (9)$$

from which the angle $\overline{G\,Q\,K}$ may be deduced. Also :

$$\overline{G\,K\,Q} = 180° - \overline{G\,Q\,K} - \overline{F\,G\,K} + 90° = 270° - \overline{G\,Q\,K} - \overline{F\,G\,K} \qquad (10)$$

$$\text{Finally, } l^1 = \frac{\sin \overline{G\,K\,Q}\,(R_2 + \tfrac{1}{2}\,g)}{\sin\,(\overline{F\,G\,K} - 90°)} \qquad (11)$$

In order to obtain the value of Y for the second branch of the switch, we deduce first the angle $\overline{O\,K\,B^1} = N^1 + N$ from the triangles $\overline{O\,K\,F^1}$ and $\overline{F^1\,K\,B^1}$. In the first of these triangles we have given :

$$\overline{O\,K} = Ro - \tfrac{1}{2}\,g,\ \overline{O\,F^1} = l^1,\ \overline{K\,O\,F^1} = 90° - F.$$

$$\left.\begin{aligned} &\text{Hence, } \tan \tfrac{1}{2}\,(\overline{O\,F^1\,K} - N^1) = \frac{(Ro - \tfrac{1}{2}\,g - l^1)\,\tan \tfrac{1}{2}\,(90° + F)}{Ro - \tfrac{1}{2}\,g + l^1} \\ &\text{and,} \qquad \tfrac{1}{2}\,(\overline{O\,F\,K} + N^1) = (\tfrac{1}{2}\,90° + F). \end{aligned}\right\} \qquad (12)$$

From which we have the angles $\overline{O\,F^1\,K}$ and $N^1$ ; also

$$\overline{K\,F^1} = (Ro - \tfrac{1}{2}\,g - l^1)\,\frac{\sin \tfrac{1}{2}\,(90 + F}{\sin \tfrac{1}{2}\,(\overline{O\,F^1\,K} - N^1)} \qquad (13)$$

In the second taiangle $\overline{F^1\,K\,B^1}$, we have given the sides :

$$\overline{K\,F^1},\ \overline{K\,B^1} = R_2 + \tfrac{1}{2}\,g + d;$$

and the opposite angles :

$$\overline{F^1\,B^1\,K} = 180° + S - \overline{F^1\,B^1\,E^1},\ \overline{K\,F^1\,B^1} = 270° - \overline{O\,F^1\,K} - \overline{E^1\,F^1\,B^1}$$

Hence we have :

$$\cos \tfrac{1}{2}\,N = \frac{\tan \tfrac{1}{2}\,(S + \overline{O\,F^1\,K} - 90°)\ (\overline{K\,F^1} + R_2 + \tfrac{1}{2}\,g + d)}{\overline{K\,F^1} - (R_2 + \tfrac{1}{2}\,g + d)} \qquad (14)$$

$$\text{And, therefore,} \qquad Y = 2\,(Ro - \tfrac{1}{2}\,g)\,\sin \tfrac{1}{2}\,(N^1 + N), \qquad (15)$$

To arrive at the value of the radius of the second branch of the switch, we have :

$$\overline{F^1\,B^1} = (\overline{K\,F^1} - (R_2 + \tfrac{1}{2}\,g + d))\,\frac{\cos \tfrac{1}{2}\,n}{\sin \tfrac{1}{2}\,(S + \overline{O\,F^1\,K} - 90°)} \qquad (16)$$

$$\text{And,} \qquad \overline{F^1\,B^1\,E^1} = \tfrac{1}{2}\,(270° + N + S - \overline{O\,F^1\,K})$$

$$\text{Therefore, finally, } R_1 - \tfrac{1}{2}\,g = \frac{\tfrac{1}{2}\,\overline{F^1\,B^1}}{\cos \tfrac{1}{2}\,(270° + N + S - \overline{O\,F^1\,K}} \qquad (17)$$

We pass now to the *turnout on a curved track.* In this case we employ the foregoing formulæ with the following alterations: 1st, Whichever is the second branch of the turnout, we must place in the formulæ of the corresponding branch of the crossing in the foregoing:

$$S = o, \text{ and } d = o.$$

2d. The values of $l$ and $l^1$ being assumed, we may omit the equations (7), (8), (9), (10) and (11).

These formulæ should be applied with the aid of logarithms, and employing the usual precautions in deducing small angles and those near 90°.

We pass next to an explanation of the tables. In calculating these the following values were assumed for the required quantities, viz.:

$g$ = gauge of track = 4′ 9″ = 4·75′.

$d$ = throw of switch rails = $5\frac{1}{2}''$ = 0·458.′ The switch rails are supposed to be 27′ 0″ long, with 7′ 0″ spiked fast, thus giving 20′ 0″ movable.

S = switch angle = 2° 37′ 27″; deduced from tan $S = \frac{6\cdot5''}{1200''}$

$l$ = 5′ 0″ constant for all frogs.

$b$ = distance between tracks, including widths of both rails = 7′ 4″ = 7·333′.

On examining these tables they will be found to be three in number, at the head of each of which is the angle of one frog of the switch, which angle is also an assumed quantity. It will be further noticed that these frogs are numbered differently from the old system, though belonging to it. The method here used is to write in one line the figures expressing the degrees and minutes of the angle of the frog. Thus a 5° 53′ is No. 543. To the engineer such a number is significative, and to the track master it as useful as No. 10. The numbers, according to this system of numeration, being large, are not easily remembered, and should, consequently, be placed on the frogs during manufacture. The change here indicated is necessary.

In the first column of the tables are the degrees of curvature of the centre line of the *tracks*, the radius of which is equal to $R_0 - \frac{1}{2}(b+g) = R_2 + \frac{1}{2}(b+g)$; while 0° signifies a straight track. The tables are carried up to 6° curves, but, if desired, the second in particular may be carried beyond. Or, curve aboves 6° degrees occurring rarely, a special calculation may be made for each case. In the last column are given the angles of the frogs working with those at the heads of the tables. All the nine cases marked with asterisks were

calculated by the preceding formulæ and with the use of Callet's logarithms. The intermediate cases were interpolated with the formula of interpolation—

$$f + nd_1 + \frac{n(n-1)}{2} d_2 + \frac{n(n-1)(n-2)}{2.3} d_3 + \&c.$$

As we had in the columns of each table three equidistant cases, we could employ this formula up to the third difference. In the majority of the columns the value of the second difference will be found to be small, which fact leads to the conclusion that the third difference would, in *all* the columns, be very small, and affect at the most only the second figures of the decimals in the columns by very little. We thus conceive that the interpolation must give results practically as good as the actual calculation by the formulæ. In the columns of R and $R_1$, we found, with a single exception, the degrees of the curves corresponding and interpolated by them in preference to interpolating by their radii. The negative values of R indicate that the curvature is the opposite of that of the positive values; or, in other words, both branches of the crossing curve in the same direction, towards the inside of the tracks. In the last column the interpolation has not been carried out to seconds, because such accuracy is neither necessary nor attainable without the third difference. *For curves lying between any two of those shown in the tables* we may obtain the required data by *ordinary* interpolation. Thus, if the data of a frog No. 543 is required for a 2° 09′ curve, all we have to do is to find the difference between the figures of the 2° and 3° curves in each column of the proper table, and add or subtract $\frac{9}{60}$ of this difference from the data of the 2° curve, according as the column increases or diminishes in passing to its foot.

It is evident that if we strictly adhere to figures given in the last column we must have a frog for every few minutes of difference in the curvature of the tracks. This is quite impracticable. We are therefore obliged to make a close approximation to the requirements of theory. Let us diminish by 30′ at a time, and to a certain extent the angles of the frogs at the heads of the tables. We have:

5° 43′ — 0° 30′ = 5° 13′, No. 513.
5° 13′ — 0° 30′ = 4° 43′, No. 453. } Group No. 1.
4° 43′ — 0° 30′ = 4° 13′, No. 413.

7° 09′ — 0° 30′ = 6° 39′, No. 639.
6° 39′ — 0° 30′ = 6° 09′, No. 609. } Group No. 2.

$$\left.\begin{array}{l} 9^\circ\ 31' - 0^\circ\ 30' = 9^\circ\ 01', \text{ No. } 901. \\ 9^\circ\ 01' - 0^\circ\ 30' = 8^\circ\ 31', \text{ No. } 831. \end{array}\right\} \text{Group No. 3.}$$

The *greatest* inaccuracy which may arise by the use of any group of these frogs, instead of those indicated in the tables, is one of only 0° 20′ in the angle. To prove that such an approximation is allowable let us suppose a switch established with the exact frog as given in the last column. Consider, next, this frog to be removed and an approximate one to be placed in its position. The rails of the switch will not fit into the latter by a certain quantity, which is, *at the most*, very nearly:—

$$3{\cdot}0 \times \sin 0^\circ\ 20' = 0{\cdot}018 \text{ ft.} = \tfrac{1}{5} \text{ in. nearly;}$$

if we take the joint of the frog to be 3 feet from either extremity. It is plain that in a distance of 12 or 14 ft. from the frog along the tangents $\overline{G\,Q}$ and $\overline{O\,F^1}$, each equal to $l^1$, the rails may be gradually deflected either way from a straight line to an extent at the end of $\frac{1}{5}$ of an inch, in order to fit into the approximate frog, without involving in the alteration any prejudicial effect. Indeed, by going back a few feet more from the frog, we might introduce a greater deflection and make, consequently, the frogs of each set vary by 0° 35′ or 0° 40′. But there is no advantage in this change. On the other side of the frog it would be necessary, in order to be very accurate in making a fit, to change slightly either the value of $R_1$ from that given in the tables or that of S. Both these variations have effects so small, however, that in practice they may be neglected. We thus perceive that the only alteration consists of a slight bending of the straight $l^1$, hardly noticeable, while the curved portions of the crossing remain circular arcs.

With a view to use the patterns of the old Nos. 6, 8 and 10 these frogs were placed at the heads of the tables. According to the preceding there would be required at least two, and at most seven new patterns. On large lines there can be no objection to having five and even ten patterns of frogs, if properly kept. Since Nos. 543, 709 and 931 are used more frequently, being employed double on straight track, twice as many of these may be manufactured as of the others.

We will give an explanation of the use of the tables in the field. The distances X and Y having been measured along the inner edge of the rail, we know, Fig. (2), the point of the frog O and the ends of the crossing D and $D^1$. By the point of the frog is here understood, not the blunt point of it, but the intersection of the sides of its angle,

a point easily obtained on the frog itself. From the point of the frog along the tangent to the rail at its inner edge, or sensibly along the inner edge of the rail, measure five feet. Again, from the extremity of this distance, and from the point of the frog, find the intersection of the distances $10 \times \sin \frac{1}{2} F$ and 5 ft. This is the tangent point F of the inner edge of the rail of the crossing; and knowing its width at top and foot we may lay down the position of either edge of its foot, which point should be marked permanently with a stake and tack as usual. Since we know the throw of the switch-rails we may locate, similarly, the position of the same edge of the foot of the rail at the tangent point near B. The distance between these two tangent points, or the chord of the arc, being measured we may from the tables obtain the value of its radius, R, and consequently deduce three ordinates for the curvature of the rail. We thus have five points to locate the rail, and the accuracy of the location may be known by the edge of its foot passing through these points. The other rail of the crossing, opposite to the one thus determined should be laid by guage. In order to determine the point R of the other frog, described from O, with a radius of

$$\sqrt{(l' - l)^2 + g^2},$$

an arc, which will cut the inner edge of the lower rail at the point required. By means of the value of R we may lay out in a similar manner, as before, the rail running from this point of frog to the other end $D^1$ of the crossing. If it is desired to commence at this end of the crossing we must first lay out the value of Y, and from O determine Q.

At the site of a crossing or turn-out the curvature of the track should be corrrected, if necessary, before proceeding to lay it down.

It is not obligatory for both tracks to be in position in order to lay out the switch, as will be seen by examining the figures. If the rail along which X and Y are measured is not down, the point O can always be determined by the conditions of it being at a distance $b$ from the inner edge of the rail beneath and at one end of Y, the other end of which is known, for it lies on a radius easily obtained through $D^1$. The point R is likewise determined from O; and knowing the curvature of the track, a perpendicular to it at R may be erected with an instrument by sighting on O and the points B and D determined.

The tangent $\overline{F O} = l$ may be laid down from O, since we know the angle of the frog. When the lower track is not in, the points $B^1$ and

$D^1$ may be ascertained by similarly erecting a perpendicular at V. The tangent $l$ at Q, may be determined similarly to $l$ at O.

A turnout may be regarded as a crossing in which the switch rails at one end are permanently fastened down. Hence if $b$=7′—4″ we may establish it just as a crossing, and with the aid of the accompanying tables.

The tables appended are calculated for a 4′ 9″ gauge, but they may be applied to a guage of 4′ 8½″ with only a slight modification. To explain this change, suppose the upper and lower rails of the two tracks to be moved towards the centre line, each ½ inch, whioh movement will cause the gauge in both tracks to be reduced to 4′ 8½″. Again, consider the lower rail of the crossing in the figures to be moved parallel to itself, the point of the frog $F^1$ continuing on the rail, until the gauge of the crossing is also reduced ½ inch. The throw of the switch at the upper end or at the branch X is reduced to 5 inches, at the lower end or at the branch Y it remains 5½ inches, and the value of $l^1$ is increased ½ cot $F_1$ inches. This alteration in the value of $l^1$ will produce changes in the lower branch of the crossing, but these are easily seen to be inappreciable in practice. The crossing will, therefore, have on curves a throw, at the end further away from the centre of the curve, of 5 inches, and at the other end, of 5½ inches, while on tangents the *positions* of these throws may be interchanged, remembering that the length of the branch for the 5 inches throw is X, and that the point of the other frog is determined by the formula :—

$$\sqrt{(l^1 - l + \cdot 042 \cot F^1)^2 + g^2}$$

which must be used also on curves to get the point of the frog $F^1$. With the sacrifice of only a little accuracy we may adopt a uniform throw of 5¼ inches throughout for a 4′ 8½″ gauge. Hence we conclude, that the tables may be used for both gauges with no other change save that already introduced in the preceding expression for the 4′ 8½″ gauge.

The usual numbers of the frogs at present in use are, as we have already remarked, Nos. 543, 709 and 931, or, according to the old enumerations, Nos. 10, 8 and 6. It is evident that if to these frogs we add those of *either* group No. 1, No. 2, or No. 3, we will have in one case 6, and in the other two cases 5, as the *total* number of frogs necessary to enable us to lay out switches on straight lines and on curves up to 6° inclusive. Thus we perceive that we need add to the present number of frogs used only 2 more, to permit their accurate

use on curves. Still, there remain certain advantages appertaining to the employment of the whole 10 indicated. These advantages are founded on the great latitude of application which a system involving such a number of frogs possesses. At every point where it is proposed to establish a switch, a choice may be made between *three* differing in the curvature of their branches, in the angles of their frogs, in the total lengths of the crossings. That switch in which the frogs make the closest approximation to perfect work, might, therefore, be adopted. Should this condition happen to be fulfilled equally well by all, we might now govern our choice by selecting the switch in which the curvatures of the branches are gentlest. Again, in large yards, where many tracks and many crossings exist, we may be, though rarely it is true, limited in the length of a new switch to be put in. If we now have several from which to choose, we may pick out the most suitable switch for the locality. However, should it be thought better to provide for such cases as they present themselves, and we are willing to dispense with the previous advantages, as being most too refined, we may fall back on the number 5 as the necessary number of our frogs.

With the view of diminishing still further this number of frogs by employing on curves, as well as on straight lines, the three usual ones, it has been suggested to the author the employment of a larger curve to the second branch Y of the switch, that it may intersect the upper rail of the lower track at a required angle. Though the suggestion is not novel to him, yet it might be well to examine it. It is evident, Fig. (2), that if the curve of the lower branch commences above the point Q, it will cut the rail beneath at a *smaller* angle than the tangent $\overline{G\,Q}$. Now as we have no frog sharper than No. 10, it follows that this frog cannot be used on the upper branch of the switch, and in consequence, we are not able to deduce a table corresponding to the first of those here submitted. The discussion of the two methods will, therefore, be confined to a consideration of only the two last tables. When two curves are made to intersect at Q, then, in order to maintain symmetry in our switch, two curves should intersect at O as well.

In connection with this change we must notice that often the radius of one branch, and sometimes of both branches, of the switch are less than 300 feet; and to introduce a *straight* frog, though only 5 or 6 feet in length, for a corresponding length of curve given by such radii would, in practice, amount to flattening suddenly the curve in that short distance by between 0.1 and 0.2 inch—an appreciable

quantity. In the method given here we must replace a portion of only *one* curve by a straight piece; and remarking that the greatest curvature of this curve is not more than 6°, the straight frog, evidently, occupies sensibly the same position as the curve. Indeed, should the curvature of the track be even as much as 8°, there would still be no sensible difference.

Let us pass now to another point. The tangent $\overline{F F^1}$, Fig (2), will, if we pursue the method suggested, be diminished by not only 2 $l$ or 10 feet, in virtue of the tangents $l$ disappearing, but it will also suffer considerable diminution by the point of tangency $F^1$ commencing nearer to O. In all cases there will be very little straight track between the two branches of the switch. In a few other cases, $l^1$ will not be sufficiently large to allow the tangent point $F^1$ moving far enough back that the curve may intersect at Q at the requisite angle. For this reason it is extremely doubtful, if a No. 6 frog at O will allow, in any curve, up to about 2°, the introduction of a No. 8 frog at Q. The second table in this system will probably, therefore, not be as complete as the third for the system here developed. In conclusion, we may remark that, even in the possible cases of the system suggested, restricted as they are in number, there will be but very little straight line, and sometimes none, between the two branches of the switch; so that, at best, we are approximating closely to a reverse curve—a curve long discarded by engineers.

If we wish to confine ourselves to the employment of only *three* frogs, and still be able to lay out switches up to 6° curves inclusive, we may, instead of using the usual numbers, use only one of them, either No. 8 or 6 with the group corresponding, No. 2 or 3. This would amount to substituting for two of the usual frogs, two others with different angles. Such a system, though applicable to small lines, yet, as regards straight track, is too limited for large ones.

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**A New Photometer.**—From the American Gas Light Journal we learn that a British patent has recently been granted to A. M. Webber for a method and apparatus for obtaining photometric measurements in terms of electrical measurements. A body, of which the electrical conductivity or resistance is altered by exposure to light, is placed in an electrical circuit, in which circuit there is also placed an electrometer, or guage of electrical resistance. Light is directed on the body, and the value of this light, or the transparency or density of any translucent substance through which the light is passed, is tested by the effect on the electrometer or resistance guage.

# THF 'PRISMOIDAL' ONE RAIL RAILWAY.

A paper read before the Franklin Institute, January, 1874.

By E. Crew.

The assertion that a train of cars can be run upon one rail would seem like an impracticability. The first impression is that it would be *impossible* to keep it on the track, especially when turning short curves. Men of experience, and practical attainments as machinists, have expressed the opinion that this *must inevitably* be the case. It would be well to remember, however, that the first efforts to utilize *steam* as a motive power, were ridiculed and treated with contempt by those whose opinions were supposed to be sustained by knowledge. Less than thirty-two years ago, the idea of transmitting communications by telegraph, was ridiculed as the dream of a visionary, by the very men who claimed to be familiar with the laws of electricity.

It is remarkable that scientific men and those claiming distinction as inventors, should be so prone to discourage the efforts of others to perfect inventions, or develop some new theory in science. When the stereoscope was first introduced in France, it was submitted to five distinguished savants in succession, who could see, or pretended to see, nothing in the instrument worthy of attention. One week before the first steamship crossed the Atlantic, and arrived safe in an American harbor, Dr. Lardner, Professor of Natural Philosophy and Astronomy in University College, London, and a distinguished author of scientific works, pronounced ocean steamship navigation a failure; and while Mr. Rœbling was building the Niagara Suspension Bridge, Sir Robert Stevens, a celebrated civil engineer and builder of light houses and bridges, declared at a banquet, that no suspension bridge could be built that would carry a train over it. Such examples should teach humility and charity. It is unsafe for any man, however learned, to assume that other men, even of modest pretensions, may not know more than he does concerning the very question upon which he assumes to be so dogmatical.

The attention of the writer, some four years since, was first given to the task of endeavoring to cheapen transportation. In the commencement of his deliberations, he took an unprejudiced view of the efforts that had been made, up to 1868, in this direction, by means of balloons and air-ships. The balloon, he considered, if ever made available between distant points, could never build up a line of communications with intermediate stations, with that regularity and cer-

tainty that now characterizes railroads and renders them indispensible to almost every community. For this reason, he decided to give no time or expense in attempts in that direction, but rather to a compromise line between balloons and two-rail railroads in such a manner as to impart the easy motion under a high speed on the former, and at a reduction of cost on the latter. He was induced to consider the velocipede as a medium to accomplish this result, and bruised himself up in a six hours experiment, in making himself master of one, from which he afterwards enjoyed many a pleasant hour's exercise on a smooth floor or surface. But he was soon satisfied that it was incompetent for any valuable service, for want of track and other motor than the muscle of man, before it could be made to enter into competition for any share of public favor. To model a suitable track for it was the first purpose, that steam might become the propelling power. By instituting a series of experiments in this direction, he became deeply interested, as he found his efforts were meeting with some success; and more particularly when his attention or experiments were upon a rail, of the prismoidal form. By a combination of wheels and axles, he found it a very simple and easy matter to lock the carriage to the prism in so perfect a manner that it would traverse many miles without the least danger of displacement, either on curves or straight lines. He was soon persuaded in his own mind that this was the proper form for a road bed for one rail. And his past two years' experience in running a short line in Alabama, leads him, unhesitatingly to announce here before this learned body, that the prismoid one rail railroad, as thus far developed, is equal to the accomplishing of the problem of cheap and rapid transportation, not only for the Grangers of the West and South, but to accomplish *elevated rapid transit* by *steam* through our crowded streets in populous cities; a task that *is now*, and has been for years past, puzzling our metropolis. He announces it for the following reasons: the prism utilizes all material used in its construction, in imparting strength both vertically and laterally; at the same time furnishing a cord of immense value in grading, bridging and trestling.

It presents a surface that is easily protected, and is best calculated to resist the action of the weather from wet to dry and freezing. It forbids traffic or travel of any kind, excepting for its own peculiar rolling stock, thereby saving much life and property that is now being destroyed daily and hourly on our present system of railroads, because of the inviting facilities offered to pedestrians, and good run-

ning ground for frightened animals, all of which tends to destroy life and property by the displacement of rolling stock. The prism in form, forbids accidents of this character. The great saving of life and property is a consideration of great moment to the traveling public as well as communities, through which lines pass. The wear and repair of said prism is far less, owing to the continuous cord that the prism makes, preventing low joints occurring from wet and freezing weather; obviates almost entirely the work on roads of ballasting and tamping under cross ties, and in the matter of grading, the same characteristic of the road that dispenses with so much ballast, offers increased facilities in crossing streams, short and deep ravines, or even long stretch of trestling; saving in one stretch, tens of thousands of dollars to the mile, that now becomes absolutely necessary under the present two rail system.

He states that, after nearly two years experimenting without arriving at the desired result, and soon after a mortifying failure in Steubenville, O., to get any car to round a curve on one rail successfully, he was riding through West Virginia, reflecting upon his experiment, when a remedy for the defect in the velocipede car fixed itself upon his mind.

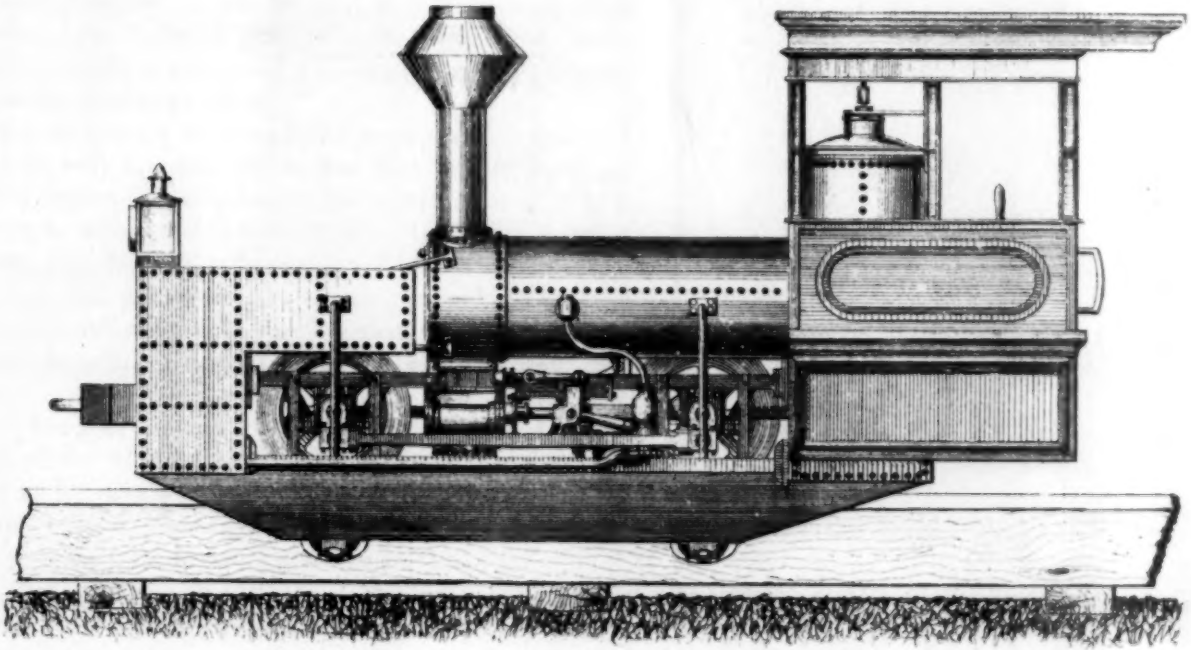
The reins were soon tightened up, and a vision came of a prismoid rail, winding through the valleys and around the hills of that rugged, but—in minerals—wealthy country, waiting for cheaper transportation than the present system offers. It was then and there, within the short space of five minutes, based upon two years patient experimenting and study, that the true theory for rapid and cheap transportation made the impression upon his mind that he shall probably never forget, and which he has ever since given his best energies to bring to public notice. First, at Steubenville, O.; second, Cincinnati Industrial Exposition in 1871, and third, at Opelika, Ala., at an elevated street railroad. Last June, while operating this line of one mile in length, the attention of a street railway company in Atlanta, Ga. (that had been organized to construct a narrow gauge road) was directed to it, and they were invited to inspect this line, when it was unanimously adopted by the company, and admitted into the streets by a unanimous vote of the City Council, in lieu of the narrow gauge road originally intended. This adoption necessitated the construction of an engine (as motive power by steam was desired), and an open order from the President, M. G. Dobbins, without stint or limit as to time or price, has enabled him to bring forth the first engine, of

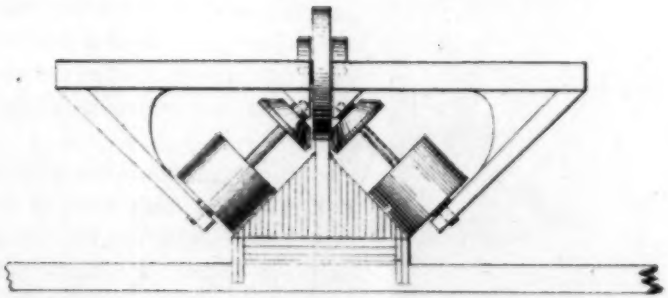
four tons weight, designed to move two coaches, each seating forty persons.

He felt prepared now to demonstrate more fully this new system, which he styled the "Prismoid One Rail Railroad," as being adapted to all classes of railroads, affording increased facilities for loading and unloading, carrying lines of track at great elevation, at a greatly reduced cost, and running curves with less friction and with absolute safety.

This system offers facilities to localities which cannot be reached by the present system, and will give rapid communication to the same, without the aid of foreign capital, enabling each community to own and control its own branch roads, its cost being less than one-half of the present system of same tonnage. A road of any carrying capacity can be constructed, the cost being the only limit, and branch roads, of but a few thousand dollars to the mile, can connect or switch its rolling stock on to a larger road of greater tonnage, and traverse it to the head of the market, without breaking bulk or transfer, as is necessary with different gauges now used. Were the Government disposed to respond to the wants of the Grangers to cheapen transportation to the sea board from the great grain fields of the West, this system could send out its branch lines to every village, from one Grand Main Prismoid Trunk Line, that could receive the smaller lines or prismoids, in trains bearing their thousands of tons. This system, he believed, would compete successfully with water in cheapness, and shorten distances as well as time consumed while in transit.

It gives great facilities and advantages in rapid travel. We usually expect, as the train moves out of a depot, in passing to New York or any other direction, that, as the speed of the train is increased, so is the lateral motion of the car, and if we attain fifty miles an hour we are under some apprehension of danger growing out of this lateral motion. Now the reverse of this might be said of the one rail system, for the higher the speed the less the liability to oscillate; so that we may infer there is no resistance to high speed growing out of lateral motion, where most, if not all, the resistance to a high speed usually comes from when two rails are used. These facts being true, he does not hesitate to say that it is practical to make the one hundred miles an hour—a feat, he believes, never yet accomplished—and that travel between New York and Philadelphia may yet be reduced in time to one hour and thirty minutes on a road with but one rail,





DEL. AND PHOTO-LITH. BY A. DICKES, 125 SOUTH 4TH ST. PHILA.

with less resistance than is now given to trains employing three hours to accomplish the distance.

It was believed and advocated in the earlier history of railroads, that eventually railroads would be built on a large scale with very broad gauge, mounted by stupendous coaches, giving a grandeur to travel, to compare with accommodations on steamboats; and many grave errors were committed in this direction, as is in evidence of the broad gauges that have changed gauge of rolling stock and track. There is a limit to width of gauge and a corresponding limit to palatial accommodation in railroad travel.

To prove the statements here made, he respectfully invited the attention of your body to a test that he was then making with the first constructed engine, in a trial trip of 500 miles; one-half of that distance on a curve whose radius is as short as the street railways turning corners, viz., 37½ feet. Over one-half of the distance had already been run, and he expected to see the engine traverse the whole distance without accident or displacement, and with less wear and repair than the ordinary engines require in going the same distance.

His engineer has been honored with many of the prominent ladies and gentlemen of the State as passengers in the cab of the locomotive while making his circuitous journey, and without a single exception all are well pleased, showing conclusively that *prejudice* would not restrain the *public* from adopting even *one rail* when shown to be safe.

In conclusion, the petition is presented of the West End and Atlanta Street Railroad Company, which gives a description of the road. The road he proposed to build is to be built and constructed as follows: First, It shall not be lower than twelve feet, except at such points as the Street Committee shall give permission to build lower, and shall be built strong and substantial. It shall not interfere with any street which it may cross.

Second, There shall be a strong and very substantial prismoid rail of wood, not less than twenty inches or more than twenty-four in base. This prismoid track will be a strong and continuous cable, with sufficient strength to support twice the amount of weight that will ever be placed upon it. It will be constructed of strong timber, securely tied, and mounted at the apex with an iron rail.

Third, Upon this road they will run a train of cars; the cars to be substantial and very strong, and propelled by an engine placed

within a car, where it cannot ever be seen from without the car. There will be no steam thrown out from the side, no sparks from the smoke stack, nor any noise made that will frighten a horse. This train will run so smoothly upon the track that there will be no rattle or clatter—nothing to annoy business men or the most sensitive ear.

Fourth. These cars are kept securely upon this prismoid track by a combination of wheels, as follows:

(1st). There are two centre wheels on the iron rail, one at either end of the car. These centre wheels are maintained upon the track by revolving flanged wheels, one upon either side. These revolving flanges lock or key this centre wheel to the track, so that it makes it utterly impossible to throw the car off the track.

(2d). There will be a wheel upon the side of the prismoid with strong wrought iron bars to the side of the car; these side wheels maintain the car in an upright position upon the track, and prevents any vibration of the car; with this system of wheels the car is maintained in equilibrium upon the track and absolutely secure. The steps to the track to occupy only the width of the guttering, and to present no obstacle to the free exit of the water, and the steps to be closely closed.

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**A New Electric Light.**—A novel and simple electrical light has been suggested by Dr. Geissler, whose name is so intimately associated with some of the most beautiful experiments that can be performed by electricity—the plan being to make an electrical vacuum tube that may be illuminated without the employment either of the induction or the frictional machine. It consists of a tube an inch or more in diameter, filled with air as dry as can be obtained, and hermetically sealed after the introduction of a smaller exhausted tube. If this outer tube be rubbed with a piece of flannel, or any of the furs generally used for exciting the electrophorus, the inner tube will be illuminated with flashes of mellow light. The light is faint at first, but gradually becomes bright and softer. It is momentary in duration, but, if the tube be rapidly frictioned, the light is rendered apparently continuous upon the principle of the persistence of vision. If the operator have at his disposal a piece of vulcanite previously excited, he may, after educing signs of electrical excitement within the tube, entirely dispense with the use of flannel or fur. This will be found to minister very much to his personal comfort. He may continue the experiments, and with enhanced effect, by moving the sheet of vulcanite rapidly up and down at a slight distance from the tube. The phenomena here described are explained to be an effect of induction.

# Chemistry, Physics, Technology, etc.

## NOTE RELATING TO RUMFORD'S DETERMINATION OF THE MECHANICAL EQUIVALENT OF HEAT.

By Prof. Robert H. Thurston.*

In his "Sketch of Thermodynamics,"† Prof. Tait gives (p. 44, §78) a *resumé* of the history of the growth of that science, and presents the following as the order of its development:

First.— Newton's grand general statement of the laws of transference of mechanical energy from one body or system to another (1687).

Second.— Davy's proof that heat is a form of energy subject to these laws (1799).

Third.—Rumford's close approximation to a measure of the mechanical equivalent (1798).

Fourth.—Fourier's great work on one form of dissipation of energy (1812).

Fifth.—Carnot's fundamental principles, his cycles of operation, and his tests of a perfect engine (1824).

Sxth.—Thompson's introduction of an absolute thermodynamic scale of thermometry (1848).

Seventh.—Joule's exact determination of the mechanical equivalent of heat, and the general reception of the true theory in consequence of his experiments (1843–9).

Eighth.—The adaptation, by Clausius and Rankine, and subsequently, with greater generality and freedom from hypothesis, by Thompson, of mathematical investigation (partly based on Carnot's methods) to the true theory; the reëstablishment of the great second law by Clausius, with Joule's experimental verification of Thompson's general results (1849–51).

Ninth.—Thompson's theory of dissipation (1852).

Here, as elsewhere, the author of the above *resumé* states fairly the work done by Rumford, but here, as elsewhere, he places his services second in importance to those of Davy, as well as in their actual

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* Presented to the American Society of Civil Engineers, December 9th, 1873.

within a car, where it cannot ever be seen from without the car. There will be no steam thrown out from the side, no sparks from the smoke stack, nor any noise made that will frighten a horse. This train will run so smoothly upon the track that there will be no rattle or clatter—nothing to annoy business men or the most sensitive ear.

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influence upon the growth of the science of Thermodynamics, and does not, apparently, consider them comparable to those of Joule.

In an earlier portion of the work (pages 7–9 §§ 13–15), the work of Rumford is correctly described, and a value of the mechanical equivalent is deduced and stated at 940 foot-pounds, the estimate being based on the assumption of 30,000 foot-pounds per minute as the true value of a horse-power. The experiment of Rumford consisted in the measurement of the heat developed by the power employed in boring cannon at the Arsenal, in Munich, and his paper describing the method and giving its results was published in the "Philosophical Transactions of the Royal Society of London" for the year 1798.

After showing that the heat evolved through the agency of friction could not have been derived from any surrounding objects, or by compression of the materials employed or acted upon, he says: "It appears to me to be extremely difficult, if not impossible, to form any distinct idea capable of being excited and communicated in the manner that heat was excited and communicated in these experiments except it be motion,"* add then goes on to urge a zealous and persistent investigation of the laws governing this motion. Estimating the quantity of heat evolved by a power which, as he states, could easily be exerted by one horse, he makes it equal to the "combustion of 9 wax candles, each $\frac{3}{4}$ of an inch in diameter."† This heat he also states as equivalent to the elevation of "26·58 pounds of ice-cold water" to the boiling point,‡ or 4784·4 thermal units, and the time occupied "one hundred and fifty minutes."

The "horse power" used by engineers as a unit of power measurement is 33,000 foot pounds per minute, but this figure, which was taken by Watt, originally, to represent the "average work of the strongest London draught-horses,"§ is much too high for application in estimation of animal power. It is well known among engineers that two-thirds of this figure is a more correct value. Rankine‖ gives, for the average draught-horse, 25,920 foot pounds per minute, or 432 per second, and this value, correct as it probably is for Great Britain, is certainly too high for Bavaria. If the horse-power of Rumford be

* Abridged Phil. Trans., Vol. XVIII, p. 286.
† *Ibid*, p. 284.
‡ *Ibid*, p. 283.
§ Bourne.
Steam Engine and Prime Movers, p. 68.

taken at 25,000 foot-pounds per minute, a value far more likely to be correct than 30,000, as assumed in "Sketches of Thermodynamics," the mechanical equivalent, as deduced from Rumford's experiment, becomes 783·8, differing only 1·5 per cent. from the value now accepted as determined by Joule a half century later, which is nearer the probably correct value than the result of any other investigation, and is even far more accurate than many results obtained by Joule himself.

Could Rumford have eliminated loss due to evaporation, radiation and conduction, of which loss he was well aware, and to the influence of which he refers, it is very certain that he would have given us a more precise determination of this quantity than even that which is above deduced.

We may then claim for Rumford:

First.—That he was the first to prove the immateriality of heat, and to indicate that it is a form of energy, publishing his conclusions a year before Davy.

Second.—That he first, and nearly a half century before Joule, determined, with almost perfect accuracy, the mechanical equivalent of heat.

Third.—That he is entitled to the sole credit of the experimental discovery of the true nature of heat.

The "second" and "third" of the *resumé* quoted should, therefore, be transposed, even if the work of Sir Humphrey Davy should not be deemed simply the supplement of earlier labor and merely corroboratory.

Benjamin Thompson, of Concord, New Hampshire, commonly known as Count Rumford, should be accorded a nobler position and a higher distinction than he has yet been given by writers on Thermodynamics.

## ON THE SANITARY CARE AND UTILIZATION OF REFUSE IN CITIES

By Dr. C. A. Leas.

A paper read before the American Public Health Association, November 13th 1873.

It has been said, and I think with much truth, that the disposition made of the offal from human habitations may with much propriety be received as an evidence or indication, not only of the cleanliness, decency, self-respect, and industry of a people, but of their moral and social condition, and when we see with what unconcern and indifference this grave and important subject of the disposal of refuse has been received and approached by legislative and executive bodies, during the past ages, we are filled with unbounded wonder and surprise, especially when we reflect that vigilant and astute sanitarians have, in all civilized countries, again and again, through many decades of the past, sounded the alarm from their watch-towers, and cried aloud from the house-tops, that these besoms of destruction, the epidemic and zymotic diseases, owe their existence in the main to defective sanitary regulations; to those active deteriorators of the public health, the heaps of festering and fermenting refuse matters, left unremoved and unutilized in and around the dwellings in our cities and towns. And not only do they thus speak forth in tones of thunder from the eternal world, but by their noxious effluvia demand removal, and are continually revealing and exclaiming, by this still small voice, that there are rich fertilizing qualities reposing within, which, if yielded up to the exhausted soils, to the demands of husbandry, will aid to promote abundance, cheapen food, and increase the demand for honest toil. Man, however, in sanitary affairs learns slowly the very important lesson that prevention is better than cure. He seems in these to have but little faith in the axiom that time ought to be grasped by the forelock, and hence he frequently slumbers and sleeps over volcanos of deadly miasm and noxious or pestilential effluvium, until, suddenly aroused by the bursting forth of blighting, withering, and devastating epidemics, which cost, besides the fearful loss of human life, sanitary reputation and commercial prestige, the expenditure of much treasure in crushing out that which might have been for a trifling outlay year by year altogether prevented. And therefore we cannot, in our mission as sanitarians, too strongly impress upon all people the important truth that in all matters relating to sanitary police and public hygiene, that what is deemed worthy to be

done ought to be promptly undertaken, and speedily and efficiently accomplished. Looking, therefore, at the question from all standpoints, we arrive at the conclusion that it is no economy to neglect or postpone the thorough cleansing of towns and cities until cholera or yellow fever has broken out, and it is no economy to discharge the contents of closets with kitchen offal into drains and sewers which debouche into tidal streams, causing thereby not only the loss of millions of dollars worth of rich manurial materials, but strewing, through the agency of the winds and tides upon the shores and docks, myriads of festering nuclii which in warm seasons exhale noxious gases to poison the atmosphere, and thus scatter disease and death among the people, to say nothing of the foul stenches that are forced back by the winds through the sewers, drains, and traps into dwellings and sleeping-chambers, causing diseases of a low type, aggravating others of a mild character, and lessening the ordinary powers of vital resistance to other morbific and destructive agencies and influences, and, indeed, man's general capability for good. Nor is it compatible with common decency to thus pollute the waters of non-tidal streams from which others must draw a supply of water for drinking, cooking, and cleaning purposes.

*The Refuse of Towns and Cities.*—But it is not the subject of sanitary police, or public hygiene, in their very direct bearings that I am called upon at this time to contemplate ; nor is it the baneful and destructive influence that unremoved excreta and other refuse matters have upon human life and health that I am expected to consider, but is the utilization of the refuse of towns and cities, or the best and most economical mode of treating and manipulating the refuse materials of large communities, so as to place them to good account, to render them sources of wealth and happiness instead of causes of misery, disease, and death. And yet this very subject has a somewhat intimate collateral connection with sanitary police and public hygiene, because, before we can utilize these refuse matters we must first get possession of them. We are, therefore, at the very threshold of our inquiry compelled to consider the best and most economical mode for their collection and transmission to safe and convenient localities, such as are out of the way and well suited for the process of manipulation.

To discuss the soundness of the wisdom which demands the restoration, as far as possble, to the soil, of such elements as were taken from it, in its efforts to furnish man with an abundant supply of food

and raiment, in order that this great storehouse of nature may be replenished with the materials wherewith to bring forth new evidences of its munificence and exhibit the infinite benevolence and loving kindness of God, would, it seems to me, be the height of folly. The economic and agricultural interests demand it, and our own common sense tells us that it is right, because in these offals and excrementitious matters, from the very nature of man's ingesta, that we find contained most valuable manurial and fertilizing qualities. And when we reflect upon the vast consumption of cerials and meats in various forms in the cities and towns of this and other countries, drawn from our fields and gardens, never again to return, then, and only then, do we begin to realize how solemn is the obligation to economize the wastes of our dwellings, stables, slaughter-houses, and streets, lanes, and alleys, and in a convenient and concentrated form, present them again to the soil from whence they came, and not only so, but at the same time to enrich the people's treasury?

*What is Refuse?*—With a view to a clearer comprehension of the nature or character of the substances refused by man, that collect about his dwelling-places, and require removal from considerations of health and convenience, we will say that they consist of all refuse and offal from houses, such as ordure and excreta; the vegetable and animal garbage from kitchens, including coal and other ashes; the sweepings of houses and yards; old and worn-out pans, kettles, and boots and shoes; the scrapings and sweepings of streets, lanes, alleys, and courts; dead animals; the unutilized materials from factories and workshops; and last, but not least, the offal and garbage from slaughtering establishments. Happily, however, for our public treasuries, that some of the substances here enumerated do not fall for their removal upon the public authorities, hence I have concluded to embrace within the scope of these remarks the utilization of only such of the refuse matters as come under the immediate and daily observation of public sanitary authorities, and as fall into their possession, either direct or indirect, for removal and disposal. And although the garbage and offal from slaughter houses as a general thing do not come under this head, and are in the main removed soon or late by the owners of such establishments to the country, and their most valuable fertilizing properties in some way or other utilized for agricultural, horticultural, or other purposes, yet I will here remark that nevertheless the efforts of many gentlemen engaged in the butchering and slaughtering of animals to preserve their premises in a cleanly and

sweet condition, a greater outrage can hardly be perpetrated upon a people than the toleration within towns and cities of such establishments. They, together with their kindred, the melting and boiling houses, soap and glue factories, and bone-grinding and crushing establishments, ought to be banished into suburban places, and the atmosphere of crowded localities saved from the contaminating influences whicht resul from the retained filth and offal for hours, and sometimes days, in closets and dung pens, festering and fermenting out in warm weather pestiferons gases, which act like slow but sure poison upon the human organism; and, besides, in suburban localities or open country the flesh of slaughtered animals can be better prepared for the markets; the atmosphere being purer, the meats are less liable to take on speedy putrefactive action. The animals themselves, from the same cause, are in a more healthy condition, and, besides, the people saved the further danger, annoyance, and damage to health and traffic, resulting from the driving of sheep, oxen, and swine through crowded thoroughfares. But it ought not to be forgotten that these open country localities for abattoirs or slaughtering purposes should be located upon streams, the waters of which are not afterwards to be used for drinking, culinary or cleansing purposes.

*Modes of Scavenging Towns and Cities.*—Various and dissimilar have been and are the modes of scavenging large towns and cities, and collecting for removal the ordinary offal and garbage from the streets and dwellings, both in this and other countries. In parts of the West Indies the dead animals and some other portions of refuse matter are referred to the buzzards for removal, and it may be said that as scavengers in this relation they are prompt and efficient, doing their work quick and well. In some European localities the owners of property are required to cleanse the public thoroughfares in front of their respective premises, and to remove the house offal, which generally accumulates in the courtyards and other places for days and weeks, until the amount proves equal to one or more wagon-loads. Such, for example, was the case in the imperial City of St. Petersburg, until the inauguration of an American scavenging system; hence it may not be wondered at that cholera had previously prevailed in that city more or less the whole year round. In other places the contiguous farmers and gardeners, with their long covered wagons and the help of their women, collect the garbage and street manure, and apply them to their lands, the removal costing the authorities nothing. Again, in others, the scavenging service is, in

whole or in part, confided to contractors, who in the main regard more attending to their own pockets than the public health and convenience. The municipal authorities of some towns and cities employ the scavenging forces, but lack fixed regulations, especially in the removal of the garbage from dwellings, the carts visiting at any and all hours of the day, thus causing the exposure of masses of filth and rubbish upon the sidewalks, in the gutters, and in and about dwellings for hours, to the great detriment of health, sight, and smell. Others cause the collection of kitchen offal and house ashes separately by two sets of carts, with the view to the utilization of the ashes for the filling of sunken lots, and the vegetable and animal offal for the feeding of swine, while others collect all together, making the same cart one heterogeneous mass of vegetable, animal, and mineral matter, and either depositing the same upon open and sunken lots, where it acts as a poison to the atmosphere of whole neighborhoods, or, to avoid this, it is covered with a layer of good earth, which makes a fair show outwardly, and smothers up, and renders less rapid the process of putrefaction. Nevertheless, it is true that good earth is a most valuable deodorant; yet it may also be regarded as certain that, if this deposited mass should be disturbed or uncovered in the process of cellar digging short of three or four years, the gases sent through the houses built upon such foundations will be productive of fearful disease and general bad health.

*The Proper Mode of Collecting Garbage.*—To secure and maintain the confidence of the people in any effort at refuse utilization, the mode and manner of its collection and removal must combine both economy and efficiency. You will, therefore, be pleased to pardon a little digression, with the view that I may, in a succinct form, lay before you my views in this relation. The garbage or kitchen offal, including coal and other ashes, yard and cellar sweepings, ought to be collected daily in the warm seasons, and at least three times per week during the other portions of the year, and with the view to constant cleanliness within doors, and a proper utilization of refuse matters, housekeepers, and all others interested, ought to be required to separate the ashes and earthy substances from the vegetable and animal offal, and in this form to present them with absolute regularity to the garbage collector, when he shall appear before the premises, and further to remove from public view the empty vessels immediately after the departure of the cart, which, together with the horses, ought to be large and substantial, and the former pro-

vided with a movable division board, so arranged as to shift little by little, fore and aft, and with an upright bolt, so that by the drawing of which the board will fly open from below upward when the cart is tilted. This partition will furnish two compartments, one for the ashes and the other for the animal and vegetable refuse, and can be shifted as the seasons advance, one upon the other, or in proportion as the ashes predominate over the vegetable and animal materials collected. Housekeepers and others ought to have sufficient warning, through the frequent sounding of a horn, aided by the ringing of team bells upon the hames of the horse, of the near approach of the cart, so that then, and not before, they may bring out their garbage; and they ought to be strictly enjoined not to expose their refuse matters upon the streets and sidewalks in advance of the time for the visit of the cart; but the officer in charge of the service ought to see to it, through the proper districting of the town or city into garbage beats, and the maintenance of proper order and discipline; that the carts appear, as to time, with almost the same degree of regularity as characterizes the arrival and departure of railroad trains. Unfaithfulness, loitering, or drunkenness on the part of employes ought to be promptly punished, as the people's health, lives, and convenience ought not to be compromised or placed in jeopardy through political or other influences. The garbage and refuse thus collected ought to be removed, either by water, rail, or carts into the country, and as much as possible out of the way of habitations and into grounds inclosed and prepared for their reception, the ashes placed under sheds and sifted, and held in stores as an absorbent and deodorant, and the vegetable and animal portions dumped into compost pits.

*How Garbage is Collected in Baltimore.*—I had the honor of inaugurating in the City of Baltimore, nearly twenty years ago, a system of collecting garbage, and it has maintained its place and popularity for nearly two decades, amid all the changes of men, measures, and parties, and when honestly, energetically and conscientiously executed, has given uniform pleasure and satisfaction to the people. And not only so, but the present Emperor of Russia, some years ago, ordered one like it to be put in execution in the City of St. Petersburg, after an Imperial Commission had reported that in all the European cities visited for the purpose of investigation, none was found equal to it as a scavenging system. The house-wives of Baltimore have been so trained and schooled, through the kindness, gentleness, and firmness of the Sanitary Department, added to their

own good practical judgment and dispositions of cleanliness, to regard the garbage-cart, not only as a necessity, but its regularity even to hours as of such grave importance as to call forth complaints when failure occur, and all such complaints ought not only to be encouraged, but carefully and promptly inquired into. The improvements or additions to this system—namely, the separation by families of the garbage from the ashes, the movable division-board in the carts, and the hauling by cart nearly two miles into the country—were adopted at my suggestion, and inaugurated nearly one year ago, with the view to the utilization of all this refuse, together with the night-soil or contents of privies, which cess-pool matter was at the same time ordered to be removed by the independent nightmen, in their carts, to the city dumping-grounds, which last regulation gave rise to an advance in the cost to property-owners of cleaning privy-vaults, and which, in its turn, together with other wise sanitary reasons, created the necessity of inaugurating the system of cleaning these places by the pneumatic suction plan, which, in case the machinery can be so perfected as to remove by suction the ordinary solid excrementitious matter, I consider to be a decided improvement, and ought by all means to form a part of the sanitary system of all large towns and cities. And again, besides the advantages in a sanitary or hygienic point, it ought to give rise to a reduction in the cost of cleaning closets nearly if not quite one-half, from the fact that the worst can and is done by day, thus giving full opportunity for double the working hours and larger loads. And, furthermore, property-owners and others interested, can see or determine with exactness the amount of service given by the night-men, and thus be enabled to audit the bills and save unrighteous drafts upon their purses and patience.

*The Model Garbage Carts.*—The movable division board in the cart saves the expense of duplicated carts in the collection of garbage—an expense the politicians feared very much. Then, again, it was supposed that to require families to provide a second garbage vessel would give rise to such an avalanche of indignation that no political party could stand against it; but, on the contrary, it was found that on the day fixed for the commencement of the garbage-separation system—which was fully made known to every family, by means of advertising and handbills circulated into every house, through the agency of the police—every family in the City of Baltimore—a city of over fifty thousand houses—had their garbage separated, and ready at the appointed hour for the garbage collector, save very few, and

the neglect of these few was found, upon investigation, to be the result of ignorance rather than unwillingness; and up to this day I am not aware of a single fine having been imposed, as provided in the law. And indeed the whole thing has become popular with the people, and thus this objection, a mere *ignis fatuus* in the minds of those that scare at shadows, has vanished, and when these fearful ones expected this overwhelming ruin they found only praise and eulogiums. At first was feared that the weight in the cart would be unequal; that either the load would be too heavy in front, and thus crush down the horse, or in the rear, and thus tilt the cart backward and hang the animal; but this difficulty soon also vanished when I showed the garbage men how to load in order to preserve the centre of gravity through the axletree.

*Disposal of Manure.*—Night-soil possesses, next to bullock's blood, the most valuable manurial properties, being well adapted to the growth of all kinds of crops, but especially those requiring a large amount of nitrogen or ammonia. I therefore ask, then, if these things be true, is it wisdom, is it true economy to allow these sources of wealth to flow through our drains and sewers into the bays and rivers, to be forever lost, or if returned in any form, to be in the shape of epidemic, pestilential, and low forms of disease, and the expenditure of millions to dredge out our docks, rivers, and ship channels, saying nothing of the damage done to the fresh water streams through their pollution by this system of drainage? Sewers and drains were originally designed to convey away the surface drainage, and this system of sending through them all refuse matters, is a serious departure from this original intention, and which ought not to be continued. I know there are difficulties surrounding this whole matter of closet vaults; the contamination of the atmosphere which they cause, especially when being cleaned by the miserable cart and bucket man and the partial contamination or damage to contiguous wells and spring. But then we must not forget that there are very few large communities dependent for a supply of water upon the resources here referred to, nor yet upon this old rotten borough system of cleansing by cart and bucket. Therefore, in view of these things, the new mode of disposing of kitchen sewage and human excreta by drains and sewers renders, in my judgment, the last end worse than the first. Until, therefore, the people can be educated up to a well-regulated system of earth or ash closets, which ought to be as soon as possible, let us, at least for the present, stand by the cess-pool plan of accumulation,

and a perfected pneumatic suction system of cleansing, and utilize, in compliance with the plain dictates of nature, for the benefit of agriculture and the taxpayers, this large mass of refuse material.

*Location and Construction of Refuse Depots.*—But now the question comes up, how are these waste matters to be utilized? The answer I will endeavor to give. And as was before stated, economy should always travel side by side with efficiency, therefore it is recommended to all towns and cities having navigable rivers running through or convenient to them, and not liable to ice-blockade, to use these to convey away, in suitable boats, tanks, and hoppers, these refuse matters to proper dumping grounds. If these, however, do not exist, or if existing, cannot be availed of, then the next best agents for transportation are railroads, and lastly, if these are not convenient or will not afford the required facilities, then there remains nothing but the horse and cart, which is the case in Baltimore, where the garbage and excreta are, by this means, transported about one mile and a half into the country. In any effort, however, to successfully utilize refuse, a market for the large amount of compost must not be overlooked in the selecting of depots for dumping purposes. This whole field must be well canvassed in its agricultural and horticultural bearings and relations, and confidence well founded that the outlet is well secured, and the demand will be quite equal to the supply. To this end and for this purpose let the section of country which may be induced under favorable circumstances to draw a supply of fertilizers from the depots, be as large as possible, and with the further view that these fertilizing boons from the towns and cities may penetrate to and enrich as far as possible those whose toil and labor contribute to the wants and necessities of the urban populations. But even if circumstances should demand the removal by horse and cart, yet the necessity will still exist for locating the dumping places so near to either railroads or navigable streams so that collateral tracks may be constructed without much cost either of construction or after working. The poudrette can be readily removed to the city in sacks or barrels and stored in warehouses for sale, but the composts cannot be so treated—those, from their crude nature, must be shipped or hauled direct to the farmers and gardeners. The ground, in quantity, should be sufficient for all present and future purposes, and having a light backward declivity, it should be inclosed by a high board fence, and containing, besides long sheds for the reception for coal and other other ashes, stowage-room for sifted ash, poudrette, old coal, old bones

and rags, boots and shoes, and implements; also, two rows of night-soil tanks, capable of holding each at least twenty three thousand gallons; large drying floors; below the tanks a number of compost pits; a small house for the protection of the superintendent by day and the watchman by night; a pump to furnish water for man and beast, and, if necessary, feeding troughs for horses, and lastly, the required supply of forks, shovels, seives, wheelbarrows, and scrapers; two or three horses and carts will also be wanted to haul materials from one locality to another.

*Mode of Handling Refuse Matters in the Dumps.*—The above is a faithful description of the mode of constructing and manner of furnishing the Baltimore dumps, and I have given them in detail because I advised their construction and equipment, and are, therefore, whether good or bad, the embodiment of my own ideas in this relation, and I will now further, from the same cause and for the same reason, describe the manner of handling and treating the refuse matter after reception within these depots. The ashes are dumped under the sheds, and then separated by the process of sifting from the coal, bones, rags, and other matters, and the vegetable and animal offal from houses into the compost pits for after treatment. The night-soil is is dumped or pumped from the wagon-tanks into the first or upper row of tanks, after passing through a grating fixed in front thereof to separate and detain from the ordure all stones, bricks, sticks, hoop-skirts, and old clothes. As the contents of privy-vaults contain, as a general thing, a larger amount of urinous than solid matter, the former rises to the surface, and when the upper tank is full, this supernatant liquor is decanted through long troughs into the compost pits containing the vegetable and animal offal before referred to, and a per centage of sifted coal-ash added to act as an absorbent and deodorant. The filling from the carts and the decanting is carried forward until the first tank is full of solid, or rather semi-solid matter. This mass or residuum is then allowed to pass through a flood-gate into the second row of tanks, where sifted coal-ash is added, which acts immediately as an absorbent and deodorand. Indeed, practical experience and observation have fully demonstrated that two thousand pounds of sifted coal-ash will, in fifteen minutes, completely deodorize six hundred gallons of manure. The amount of sifted ash now ordered to be added to the ordure for the making of poudrette is two parts of the latter to one of the former, or one of ash to two of night-soil, though, for the purposes of greater strength and concen-

tration for transportation purposes, one part of sifted coal-ash may be added to three or four parts of night-soil, which makes a beautiful dry poudrette, and will, I doubt not, prove quite equal in its fertilizing qualities to the best guano, and far superior to many of the fertilizing agents now sold in the markets for from $40 to $60 the ton. The mixture thus made in the second row of tanks is, after deodorization, thrown upon the drying floor about three inches deep, which, if the weather be favorable, will dry in a few hours. The mass is then removed and thrown out upon a heap; a process of heating takes place, in which the great and small lumps or clods that were formed upon the drying-floor fall or crumble into powder. The whole is then run through a sieve or screen, and is the fine or double-refined poudrette —according to the capacity of the sieve—which is sold by the Corporation of Baltimore for from $15 to $20 the ton, and its popularity is I am informed, being well established with the farmers and gardeners who have nsed it upon their lands. This poudrette, thus made from no other materials than the raw contents of privies and coal-ash, is a fine, dry, inodorous powder, which might, with great propriety, be exhibited in a parlor filled with ladies and gentlemen of the most refined character. Composed of three parts of night-manure to one of coal ash, and upon examination it will be seen how perfectly the ammonia is fixed, and how thorough and complete has been to the deodorization. The compost made from the kitchen offal, a portion of sifted ash and the supernatant liquor from the manure tanks, is sold by the cart load of forty cubic feet, or thirty bushels, at seventy-five cents, but it is an exceedingly rich manure, as can well be understood from its miscellaneous or heterogeneous character, being composed of rich vegetable and animal matters. This manure is the most fertile of all the fertilizing agents, and has, doubtless, a far greater monied value, and which will probably be yet realized, when the authorities shall have connected the dumps with the railroads that pass near them, so that the far distant fields and gardens can be allowed, upon reasonable conditions, to partake of or share in this ocean of marrow and fatness. The old rags and bones are separated as before stated, from the ashes and also from the kitchen offal and night-soil and sold, considerable revenue being derived therefrom; and the old boots and shoes can, I understand, be reduced to powder by the process of burning and sold for the case hardening of iron, the old coal either sold for reburning or for the making of roads; so it will be seen that the utilization of everything collected has been

provided for, save the old pans and kettles, and I do not despair even of these. It may be, that ere long, some branch of business will require them for some useful purpose.

*The Utilization of Scrapings and Ashes.*—It has been stated that coal-ashes possess no agricultural or fertilizing value whatever, but such is evidently not the case, for besides the trace of wood-ash that they contain, which yield alkaline salts, they have in themselves properties, chemical and mechanical, which the soil requires, and I have seen, in our Baltimore dumping grounds, splendid tomatoes, pumpkins, citrons and tobacco growing from a bed of pure coal-ash and cinders. A sample of the Baltimore City poudrette was submitted to Prof. Leibig for analysis, composed of one part of ash to one of night-soil, and it was declared to have a value of $15 per ton of 2000 pounds, when viewed in the light of the report of the United States Commission of Agriculture at Washington, and as compared with the double-refined poudrette of the Lodi Manufacturing Company of New York, an article which, it is said, finds a ready sale at $25 per ton. If, therefore, this Baltimore poudrette of one to one has such a value, what will be the value of a poudrette made of from say four of human ordure to one of ash? The answer will probably prove it to be quite equal to the best guanos. The analysis of Prof. Leibig exhibits the constituents to be ammonia, phosphoric acid, bone-phosphate of lime, alkaline salts, and lime, all of which are important and even necessary in the growth of crops.

I have made no special reference to the utilization of the scrapings and sweepings of streets, because these generally find a ready sale. They, however can I doubt, not be made of greater value by admixture with the compost matters, as the supernatant liquor from the night-soil tanks is quite sufficient for complete saturation, even after these shall be added.

I have also not referred to the plan of utilization by irrigation as practiced in some parts of England and Scotland, through the instrumentality of ditches, pipes and jets. This plan comprehends the utilization in the form of liquid manure or sewer water, in which the kitchen offal and other matters are held in solution, and suspension. This mode of applying refuse matters to useful purposes admits of the discharge of refuse matters into drains and sewers for collection at the mouths of the latter, but I apprehend it could not be availed of to any extent in this country. I, therefore, even if it were compatible with a well regulated sanitary system, dismiss it as being impracticable, at this time at least.

# Franklin Institute.

HALL OF THE INSTITUTE, February 18th, 1874.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

Thh minutes of the last stated meeting and of the special meeting, held Friday, January 30th, were read and approved.

Some doubt having been thrown upon the correctness of the clause of the minutes of the last stated meeting referring to a proposed amendment of Mr. J. W. Nystrom, it was, upon motion of that gentleman, resolved that the same be considered to be a resolution passed. Carried.

The passage in question would therefore read:—

"*Resolved*, That the Institute shall hold a conversation meeting on the second Friday of each month, from 8 to 10 P. M., except in the months of July and August.

"That the members shall be at liberty to converse freely in the hall of the Institute during the conversation meeting; and that no lecture or other meeting shall be held at the Institute during the conversation meeting."

The Actuary presented the minutes of the Board of Managers, and reported that at their stated meeting held February 11th, 1874, donations to the Library had been received from the following sources, viz.:

Patentee's Manual, showing the manner of Securing Inventions by Letters Patent in Canada and Foreign Countries. From Charles Legge & Co., Montreal.

Comptes Rendus hebdomidaires des Sciences de l'Academie des Sciences, Nos. 2 to 20, 1873. From the Academy, Paris.

Bulletin de la Société d'encouragement pour l'Industrie Nationale, for August, September, October and November, 1873. From the Society, Paris.

Annales de Chimie et de Physique, for August, September, October and November, 1873. From the Editor, Paris.

Proceedings of the Philosophical Society of Glasgow, 1872—73. From the Society.

Proceedings of the American Iron and Steel Association at Philadelphia, November 20th, 1873. From the Association.

Bulletin of the National Association of Wool Manufacturers, October—December, 1873. From the Association.

The Actuary reported also the fact that the Board had appointed Messrs. Chas. Bullock and Bloomfield H. Moore, Curators; and D. S. Holman, Actuary for the current year. He likewise reported the following resolution:—

"*Resolved*, That the Board of Managers recommend to the Institute the passage of a resolution instructing the President to express by letter to Mr. George W. Childs and to Mr. W. V. McKean, of the *Public Ledger*, the thanks of the Institute for the carefully prepared editorial in its issue of February 3d, which was so earnest in its advocacy of the utility of the Franklin Institute."

Mr. Nystrom moved that the recommendation of the Board, as read, be adopted.

Mr. Orr moved to amend by including in the vote the *North American* newspaper, and supported his request by reading from a copy of the paper in question, of that day, a very appreciative and encouraging editorial. The amendment was accepted, and the amended motion was carried.

The President next announced the following standing committees for the current year:—

*Library.*

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| Chas. Bullock, | William H. Wahl, |
| Samuel Sartain, | C. A. Evans, |
| William P. Tatham, | B. H. Moore, |
| Jos. W. Wilson, | J. W. Nystrom, |
| Dr. Geo. F. Barker, | Dr. Isaac Norris, Jr. |

*Minerals.*

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|---|---|
| F. A. Genth, | John C. Trautwine, |
| Theo. D. Rand, | Edward F. Moody, |
| Samuel B. Howell, | R. E. Griffith, |
| C. S. Bement, | Jos. M. Wilson, |
| William H. Wahl, | F. H. Reichard. |

*Meteorology.*

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| Pliny E. Chase, | Thos. S. Speakman, |
| Hector Orr, | James A. Kirkpatrick, |
| Dr. Isaac Norris, Jr., | David Brooks, |
| Robt. E. Rogers, | Alex. Purves, |
| John Wise, | William H. Wahl. |

*Models.*

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| Wm. B. Bement, | Edward Smith, |
| F. B. Miles, | D. S. Holman, |
| Edward Brown, | J. B. Knight, |
| Theodore Bergner, | C. Chabot, |
| John Gœhring, | Wm. B. LeVan. |